Analysis of Energy Efficiency Project Activities and Key Methodological Issues

Prepared for:

United Nations Framework Convention on Climate Change

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Acknowledgements

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List of Abbreviations and Acronyms

BAU	business as usual
BM	build margin (for electricity generating units)
CDD	cooling degree day
CFL	compact fluorescent lamp
DEER	California Database for Energy Efficiency Resources
DSM	demand-side management
ECM	energy conservation measure
EE	energy efficiency
EEM	energy efficiency measure
EM&V	evaluation, measurement, and verification
ER	emission rate
EUL	effective useful life
GHG	greenhouse gas
HDD	heating degree day
HVAC	heating, ventilation, and air conditioning
IPMVP	International Performance Measurement and Verification Protocol
ISO	International Organization for Standardization
kW	kilowatt
kWh	kilowatt hour
M&V	measurement and verification
MW	megawatt
MWh	megawatt hour
NEB	non-energy benefits
NTGR	net-to-gross ratio
QAG	quality assurance guideline
TBE	theory-based evaluation
T&D	transmission and distribution

Executive Summary

1.1 Background and Objectives

The potential benefits associated with using energy efficiency as a strategy for climate change mitigation as well as for sustainable development are very large. However, since energy efficiency currently accounts for only a small fraction of projects in the Clean Development Mechanism (CDM) pipeline, the CDM Executive Board (Board) is interested in exploring possibilities for creating an environment that would better enable more qualified energy efficiency projects and programs under CDM. Thus, this report examines current international practices for documenting the energy savings and avoided emissions associated with end-use energy efficiency programs; with the expectation that these practices can be used effectively within the CDM program to increase the number of Certified Emission Reductions (CERs) associated with end-use energy efficiency.

There appear to be two general issues associated with implementing more energy efficiency activities within the CDM process. First of all, individual end-use energy efficiency projects tend to produce relatively small reductions even though they can yield impressive levels of savings from large-scale programs (programs being made up of a large number of individual projects). Secondly, there are methodological challenges associated with quantifying and documenting the indirect, avoided greenhouse gas (GHG) emission reductions from energy efficiency projects and programs, as well as assessing the additionality and attribution of efficiency activities' causes and effects (traceability). Both of these issues are related and both lead to high transaction costs per unit of CER for individual efficiency projects.

In order to begin achieving efficiency's full potential of GHG savings, program level activity is necessary to address the first issue and thus CDM baseline and monitoring methodologies suited for large-scale programs are also necessary that address the second issue. While some CDM energy efficiency methodologies do exist and can be used for Programs of Activities (PoA), further development of CDM guidelines and methodologies that both meet the Board's criteria for credible CERs and are cost-effective to implement (i.e. low transaction cost) would enhance opportunities for achieving more energy efficiency based CERs.

This report shows how a number of public and private entities use program level evaluations to develop reliable energy savings estimates with acceptable uncertainty limits, at reasonable transaction costs; and through the use of sampling, do not require a census of project level measurement and verification. Furthermore, while not as well established or tested, this report also describes methodologies for translating energy savings from efficiency programs into avoided emissions.

1.2 Energy Efficiency Program Approaches and Key Evaluation Strategies

Evaluation involves real time and/or retrospective assessments of the performance and implementation of a program. There are two key objectives of evaluations:

- Document and measure the effects of a program in order to determine how well it has met its goals, and

- Understand why those effects occurred and identify ways to improve current and future programs as well as select future programs.

Many energy-efficiency evaluations are oriented towards developing retrospective estimates of energy savings attributable to a program, in a manner that is defensible in regulatory proceedings that are conducted to ensure that public funds are properly spent. However, the role of evaluation can go well beyond simply documenting savings to actually improving programs and providing a basis for future savings estimates. If applied concurrently with program implementation, evaluations can provide information in real time to allow for as-needed course correction. In summary, evaluation fosters more effective programs and justifies increased levels of energy-efficiency investment. Perhaps this was best described by John Kenneth Galbraith and William Edwards Deming, "*Things that are measured tend to improve*".

For determining savings from energy efficiency activities there are two types of relevant evaluations:

1. *Impact evaluations* determine the impacts (i.e. energy savings) and avoided emissions that directly result from a program. Impact evaluations also support cost-effectiveness analyses that evaluate relative program costs and benefits.
2. *Market effects evaluations* estimate a program's influence on encouraging future energy-efficiency projects because of changes in the energy marketplace. These evaluations are primarily, but not-exclusively, used for programs with market transformation elements and/or objectives and can indicate, although generally with less rigor than pure impact evaluations, energy savings and avoided emissions.

For CDM, the most relevant type of evaluation, and the focus of this report, is impact evaluation. This report discusses both project and program impact evaluation methods, although the focus of the discussion and recommendations are on program evaluation. In this context, a project is a single activity at one location, for example an energy-efficient lighting retrofit in an office building. A program (or PoA) is a group of projects with similar characteristics that are installed in similar applications, such as a utility program to install energy-efficient lighting in commercial buildings, a company's program to install energy management system in all of its stores, or a government program to improve the efficiency of its public buildings. Programs are typically evaluated using a sample (versus census) of projects with the results then systematically applied to the entire program "population" of projects.

In the efficiency industry the three impact evaluation results that are typically reported are:

- ***Estimates of gross savings.*** Gross energy savings refer to the change in energy consumption that results directly from program-promoted actions taken by program participants (e.g., installing energy efficient lighting), regardless of the extent or nature of program influence in causing their actions.

- ***Estimates of net savings.*** Net energy savings refer to the portion of gross savings that is attributable to the program. This involves separating out the impacts that are a result of other influences, such as consumer self-motivation. Given the range of influences on consumers' energy consumption, attributing changes to one cause (program) or another can be quite complex.

- ***Estimates of co-benefits***. A co-benefit commonly documented and reported is avoided air emissions. Avoided emissions refer to the air pollution or greenhouse gases that would have been emitted if more energy had been consumed in the absence of the energy-efficiency program. These emissions can be from combustion of fuels at an electrical power plant or from combustion of heating fuels, such as natural gas and fuel oil, at a project site. Other co-benefits are also sometimes reported, and can be related to CDM sustainable development goals, such as reduction in other environmental impacts associated with energy production, e.g. water use, as well as comfort and productivity improvements and local job creation.

Energy savings and avoided emissions cannot be directly measured. Instead savings are determined by comparing energy use and demand after a program is implemented (the reporting period) with what would have occurred had the program not been implemented (the baseline). The baseline and reporting period energy use and demand are compared using a common set of conditions (e.g., weather, operating hours, building occupancy, etc.) through adjustments so that only program effects are considered when determining savings.

Procedures for evaluating and reporting verified savings from end-use efficiency activities are well established, having evolved during the past thirty years into a body of knowledge agreed to and shared by researchers, regulators, equipment vendors, and private and public energy service companies and providers. The literature associated with energy efficiency programs is therefore mature and extensive. A bibliography of current energy efficiency program and program evaluation literature is included in Appendix A.

The most common practices for implementing the impact evaluation process for determining energy savings and avoided emissions involve:

1. Determining gross program savings using one of the following approaches:
    a. One or more measurement and verification (M&V) methods, from the IPMVP[1], are used to determine the savings from a sample of projects and these savings are then applied to all of the projects in the program.
    b. Deemed savings that are based on historical and verified data are applied to conventional energy-efficiency measures implemented in the program.

1 Measurement and verification (M&V) is the process of using measurements to reliably determine actual savings created within an individual facility. IPMVP is the International Performance Measurement and Verification Protocol (available at www.evo-world.org) - a standard within the efficiency industry. Evaluation is determining savings from a program. EM&V (evaluation, measurement and verification) is a catch-all term for both. Note that within the efficiency industry M&V stands for measurement and verification versus monitoring and verification.

c. Statistical analyses of large volumes of metered energy usage data are conducted.

In some cases combinations of these approaches are utilized, particularly the deemed savings and M&V approaches.

2. Converting gross program savings to net energy savings using a range of possible considerations. The primary, but not exclusive, considerations that account for the difference between net and gross savings are free riders (those who would have implemented the same or similar efficiency projects without the program now or in the near future) and participant and non-participant spillover. Non-participant spillover comes from efficiency projects implemented by those who did not directly participate in a program, but which nonetheless occurred due to the influence of the program. Participant spillover is defined as additional energy efficiency actions taken by program participants as a result of program influence, but actions that go beyond those directly subsidized or required by the program. Net savings are determined using one of the following approaches:
    a. Self-reporting surveys through which information is reported by participants and non-participants without independent verification or review,
    b. Enhanced self-reporting surveys through which self-reporting surveys are combined with interviews and documentation review and analysis, and/or
    c. Statistical models that compare participants' and non-participants' energy and demand patterns, their knowledge about efficiency options, and/or the tradeoffs they are willing to make between efficiency options and the costs of purchasing and installing them.
    d. Stipulated net to gross ratios (ratios that are multiplied times the gross savings to obtain an estimate of net savings) that are based on historic studies of similar programs.
3. Avoided emissions are calculated by either (a) applying emission factors (e.g., kilograms of CO_2 per MWh) to net energy savings or (b) using emissions scenario analyses, e.g., using computer models to estimate the difference in emissions from grid-connected power plants with and without the reduced electricity consumption associated with an efficiency program. A variety of approaches can be used to calculate emission factors or prepare scenarios analyses ranging from just using annual average emission factor values to preparing detailed hourly calculations of displaced energy sources. However, whether emissions are actually avoided depends on whether the energy savings are truly additional to what would have occurred without the program's influences, whether all significant emissions sources associated with a program were taken into account, and the scheme under which any affected emission sources may be regulated.

1.3 Framework for Analysis and Programs Selected for Review

To provide the Executive Board with an indication of how efficiency impact evaluation is conducted, a selection of existing energy efficiency programs operated in the U.S. and other countries were reviewed using a framework that provides program information and impact evaluation practices. Details regarding the programs selected for review are summarized for comparison across four primary dimensions: program descriptions, program size, program types, and impact evaluation processes. Information from the following regions is examined in this report:

1. United States - Energy efficiency programs implemented for the California Public Utilities Commission via California's four investor-owned utilities: Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison and Southern California Gas Company.

2. United States - New York State portfolio of energy efficiency programs operated by the New York State Energy Research and Development Authority under the direction of the New York Public Service Commission.

3. United States - Oregon suite of energy efficiency programs ordered by the State legislature and operated by the Energy Trust of Oregon.

4. United States - Texas energy efficiency programs operated by the State's investor-owned utilities as directed by the Public Utility Commission of Texas.

5. United States - Vermont energy efficiency programs operated by Efficiency Vermont, the administrator established by the State legislature.

6. Non U.S. – Summary of eight programs selected from, in consultation with the author of, the International Energy Agency's report *Evaluating Energy Efficiency Policy Measures and DSM Programs; Volume II, Country Reports and Case Examples Used for the Evaluation Guide Book*.[2] The programs operate in Belgium, Canada, Denmark, France, Italy, Republic of Korea, The Netherlands, and Sweden.

1.4 Discussion

Arguably, the methodologies most readily applicable to estimating GHG reductions from energy efficiency is impact evaluation as it is conducted most notably in the U.S. This may be because a primary concern of U.S. regulators implementing energy efficiency policy has been to ensure that the savings are a resource that can be directly compared with energy supply. Although evaluating energy impacts is an important issue whenever efficiency programs are evaluated, some other jurisdictions and countries focus more attention on metrics such as numbers of participants reached, whether codes and standards are enforced, and overall energy intensity per capita. Impact evaluation approaches, for example, some of the U.S. approaches documented in

[2] H. Vreuls. *Evaluating Energy Efficiency Policy Measures and DSM Programmes, Volume II: Case Studies.* International Energy Agency and SenterNovem. 2005.

this report, that lead to reliable estimates of energy consumption reduction in units of energy (e.g. kWh per year) lend themselves most readily to methods for estimating GHG reductions.

1.5 Conclusions and Recommendations

The impact evaluation strategies described in this report are discussed in light of key questions raised by the CDM Executive Board with respect to efficiency program evaluation. The final section of the report presents conclusions derived from the research and recommendations for how the CDM Board might proceed in developing guidelines to support programmatic energy efficiency under the CDM mechanism. These are summarized below.

1.5.1 Conclusions

Unfortunately, basic information on efficiency program design and evaluation requirements is neither readily available nor easily comparable between different jurisdictions. However, our review of the current literature and an examination of program offerings and impact evaluation strategies in selected jurisdictions did lead to the following conclusions:

1. Quantifying savings for end-use energy efficiency programs is an established discipline and its methods can yield reliable and actionable energy savings reports.

2. CDM energy efficiency program evaluation approaches can be based on these established impact evaluation methods.

3. Reliable impact evaluations can be conducted, even if project-specific data are not available or cannot be cost-effectively collected for each project, through the use of existing data from comparable efficiency activities or through the use of limited studies to determine values that ca be applied broadly. This approach is called using *stipulated* or *deemed* estimates. However, this approach does require quality-control mechanisms.

4. A degree of uncertainty is inherent with measuring the results of energy efficiency but statistical techniques can yield acceptable confidence in the evaluation results.

5. The techniques for estimating net savings attributable to specific energy efficiency programs are changing in markets saturated with multiple efficiency programs.

6. While not as established as energy savings determination approaches, there are available methodologies for converting efficiency activity savings into avoided GHG emission values.

1.5.2 Recommendations

Following on the conclusion that established end-use efficiency evaluation techniques can be used to accurately estimate savings impacts with accuracy levels that meet societal and regulatory needs, there are concrete steps that the Board can take to build on this body of knowledge to promote energy efficiency under CDM.

1. Convene a panel of international end-use energy efficiency experts (an expert panel) to develop CDM specific end-use energy efficiency documents. These documents would include program implementation templates, deemed savings values, and program evaluation methodologies that can be applied to the most common efficiency activities (e.g. lighting and motors retrofits). Then update these documents using actual CDM implementation experience and add additional efficiency activities documents as the marketplace establishes the need.

2. Develop deemed savings values to stipulate both energy savings and GHG emissions reductions for common energy efficiency actions.

3. Request that current energy efficiency program administrators voluntarily prepare and make public basic information on program implementation and evaluation requirements.

1.6 Report Organization

The report is organized as follows: Section 2 provides an introduction to the report and background information. Basic program types and evaluation approaches are described in Section 3. Section 4 outlines the selection criteria for programs examined in Section 5, and the framework for analysis in that Section. The programs, evaluation strategies and evaluation literature are discussed in Section 6, focusing on a series of key questions raised by the Secretariat to the CDM Executive Board regarding energy efficiency program evaluation. Conclusions and recommendations are presented in Section 7. An annotated bibliography of current literature on energy efficiency program evaluation is included in Appendix A, and a Glossary of Terms is included as Appendix B.

Background and Objectives

The purpose of this project is to assist the United Nations Framework Convention on Climate Change (UNFCCC) Clean Development Mechanism (CDM) Executive Board (Board) and Methodology (Meth) Panel enhance opportunities for energy efficiency projects and to quantify their resulting emissions reductions. This report examines impact evaluation for end-use energy efficiency programs, with the expectation current practices can be extended to account for GHG emissions reductions.

As noted at the CDM Executive Board's 31st meeting, the potential for using energy efficiency as a strategy for climate change mitigation is large, but there are methodological challenges for verifying emissions reductions from energy efficiency projects and assessing the requirements for additionality. Since energy efficiency currently accounts for only a small fraction of projects in the CDM pipeline, the Board is interested in exploring possibilities for creating an environment that would better enable the provision of qualified energy efficiency projects and programs under CDM.

Material presented in this report provides guidance on high-level issues in end-use energy efficiency measurement and verification (M&V) through a review of industry standard approaches used in existing energy efficiency programs. The advantages and disadvantages of these approaches are discussed in the context of key technical and policy criteria.

2.1 Background

Energy efficiency reduces greenhouse gas (GHG) emissions by lowering the demand for fossil fuels used in the production of electricity and/or thermal energy. With approximately 61 percent of all human induced (anthropogenic) GHG emissions (and about 75 percent of all CO_2 emissions) coming from energy related activities, mitigating climate change requires significant changes in the energy industry[3]. Energy efficiency is particularly important for controlling GHGs because of its inherent cost-effectiveness and the lack of commercially available greenhouse gas "scrubber" technologies. Energy efficiency could potentially account for more than half of the energy-related emission abatement potential achievable within the next 20–40 years, as identified by the International Energy Agency (IEA) World Energy Outlook (2006), the Fourth Assessment of the Intergovernmental Panel on Climate Change (2007), and the McKinsey Cost Curve (2007)[4].

Investment in energy efficiency is not only crucial from the perspective of climate protection; it can make an important contribution to sustainable economic and social development in both

[3] K. Baumert, T. Herzog, J. Pershing. *Navigating the Numbers: Greenhouse Gases and International Climate Change Policy.* World Resources Institute. 2005.

[4] *Christiana Figueres and Michael Philips. Scaling Up Demand–Side Energy Efficiency Improvements through Programmatic CDM, prepared for Energy Sector Management Assistance Program and The World Bank Carbon Finance Unit. 2007.*

developed and developing countries.[5] Energy efficiency enables the overall economy to be more energy and resource efficient in many cases by delivering energy services at lower cost than traditional generation, by reducing the amount and cost of pollution, and promoting technological, economic and financial innovation and related job growth in sustainable and/or high-tech industries.[6] For developing countries facing the challenge of providing adequate energy services to growing populations and economies, investments in energy efficiency improvements are attractive, because they can often be implemented rapidly in addition to cost-effectively.[7]

Energy efficiency involves products, systems or practices using less energy to provide the same or improved level of service in an economically efficient way as compared to a conventional approach. In broadest terms, there are three types of energy efficiency. The categories require distinct approaches, technologies, regulatory frameworks and methods for evaluation, and they tend to be handled separately in current practice and literature.

- *Energy supply*
  Improvements in the equipment or techniques used to generate electricity, either at central station plants or onsite facilities.

- *Transportation*
  Improvements in efficient transport technologies or systems.

- *End-use*
  Improvements in buildings, facilities or other stationary sources that use energy to accomplish activities in the industrial, commercial, residential and service infrastructure sectors. Examples of energy end-uses include manufacturing, lighting, heating, cooling, and water pumping.

2.1.1 End-use energy efficiency

The focus of this report is on end-use energy efficiency, which is part of the general category of activities known as demand side management (DSM) – encouraging customers to modify their level and pattern of energy consumption. Recent influential publications indicate that dramatic increases in end-use energy efficiency will be necessary in the coming years in order to meet targets for mitigating climate change. The International Energy Agency (IEA) indicates in its latest Alternative Policy Scenario that end-use energy efficiency will account for 65 percent of

[5] A. Niederberger. *Energy Efficiency Projects in CDM and JI: Seminar Issue Paper*. UNIDO/CTI/UK.Trade & Investment Seminar. 2007.
[6] A. Neiderberger and R. Spalding-Fecher. *Demand-Side Energy Efficiency Promotion Under the Clean Development Mechanism: Lessons Learned and Future Prospects.* Energy for Sustainable Development, Volume X, No. 4. 2006.
[7] Spalding-Fecher, R, Roy, J., Wang, Y., and Lutz, W. *Potential for Energy Efficiency: Developing Nations.* Encyclopedia of Energy, 5, 2004.

energy-related CO_2 abatement by 2030; the *Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC)* and others have drawn similar conclusions.[8,9]

In addition to energy savings, demand savings, and avoided air emissions, there are other potential benefits of energy efficiency. These include:

- Avoided transmission and distribution capital costs and line losses
- Reliability net benefits
- Voltage support and power quality benefits
- Environmental net benefits (in addition to air pollution and climate impacts the most common considerations relate to water)
- Energy price effects
- Economic impacts (e.g., employment, income, trade balances, tax revenues)
- National security impacts.

Accordingly, the CDM Executive Board is interested in enhancing opportunities for energy efficiency projects to be implemented under the CDM.[10] Despite the large potential for energy efficiency to reduce GHGs, energy efficiency comprises only a modest share of projects in the CDM pipeline. End-use energy efficiency projects represent about 6 percent of current projects and account for just 1 percent of the certified energy reductions (CERs) expected through 2012.[11]

2.1.2 Factors affecting provision of energy efficiency through CDM

In a note for a recent meeting, the Board observes that "A critical factor in promoting any CDM project activities is the availability of approved methodologies that are easy to implement and do not impose significant transaction costs on the project activities …" Processes for seeking project approval are cumbersome and require lengthy approval periods, often more than a year. Energy efficiency projects have had a particularly difficult time seeking approval. Of almost 90 methodologies for energy efficiency that have been submitted, only one out of three has succeeded. This is substantially lower than the overall success rate for new methodologies, which is about 50 percent.

One source of difficulty is that traditional CDM processes for approving baseline and monitoring methodologies tend to focus on large scale, single site emission reduction opportunities that occur at a single point in time. (In certain instances, several sites can be "bundled" together, but

[8] N. Tanaka. *Mind the Gap -- Quantifying Principal-Agent Problems in Energy Efficiency.* Organisation for Economic Co-operation & Development/International Energy Agency. 2007.
[9] International Panel on Climate Change (IPCC). *Climate Change 2007*. IPCC. 2007.
[10] Secretariat for the United Nations Framework for Climate Change Convention CDM Executive Board. *Note by the Secretariat for EB32, Informal Consultations: Options to Enhance Energy Efficiency Under CDM*. 2007.
[11] J. Fenhann. *CDM Pipeline 10-01-2007*. United Nations Environmental Program (UNEP) Risø Centre. 2007.

in essence these constitute a single project.) A typical project of this type would be a renewable energy plant built to displace the use of fossil fuel for producing electricity. Some end-use energy efficiency projects do create significant emissions reductions at a single site and lend themselves to site or project specific measurement techniques. These projects primarily involve improvements in buildings and processes at large energy intensive industrial facilities. However, in most cases end-use energy efficiency reductions (and associated GHG reductions) are achieved by employing programs to implement a number of relatively small interventions at a wide variety of sites over a period of time. Traditional CDM policies for approving monitoring and baseline methodologies have been less conducive to activities with these dispersed characteristics.

This emphasis on large, singular projects is reflected in the nature of end-use energy efficiency that has been approved to date and/or is in the current CDM pipeline. The greatest share of end-use efficiency projects has been in the industrial sector, representing more than 80 percent of the energy efficiency projects and CERs from energy efficiency expected by 2012. Currently, six standard methodologies for certifying emissions reductions have been approved for the industrial sector. Conversely only one primary method has been approved for households (replacement of incandescent lamps with fluorescent lamps), and one for infrastructure services (water pumping).

In an effort to alleviate these obstacles to implementation of energy efficiency and other GHG-reducing activities that are less suited to project-specific measurement, the Council of Parties/Meeting of Parties (COP/MOP) in 2005 proposed a set of simplified procedures for small scale projects, and "programs of activities." These guidelines offer the benefit of simplified approval processes and methodologies for small scale CDM (SSC) projects, and those with distributed approaches. The rules have undergone several revisions; current policies and forms are posted on the UNFCCC/CDM website.[12] Although the rules initially capped the size limit for SSCs at activities designed to reduce energy consumption by no more than 15 GWh per year, the cap has recently been raised to 60 GWh per year. This represents an important step toward encouraging approval of larger scale energy efficiency programs.[13]

2.1.3 Key Methodological Challenges for Energy Efficiency Project Activities under CDM

Although there is a great deal of interest in streamlining the approval process for end-use energy efficiency, verifying GHG reductions and assessing additionality requirements raises a number of methodological issues. In a note for the thirty second meeting of the Board, the Secretariat raised concerns about the following specific issues.

1. Increasing the number of approved methodologies for end-use energy efficiency in the industrial, commercial, residential and services sectors.

[12] http://cdm.unfccc.int/ProgrammeOfActivities/index.html
[13] Figures, C., and Philips, M. *Scaling Up Demand-Side Energy Efficiency Improvements through Programmatic CDM – ES Technical Paper 120/07*. World Bank Carbon Finance Unit, Energy Sector Management Assistance Program. 2007.

2. Measuring energy savings and concomitant GHG reductions with adequate accuracy and precision, given the number of independent factors that may affect energy consumption that are not related to energy efficiency improvements (e.g., weather, energy prices, operation and maintenance practices.

3. Setting boundaries for the analysis.

4. Equipment lifetime for retrofit, replacement and new construction projects.

5. Establishing appropriate baseline scenarios that account for historical usage, changes in operation, technology degradation and naturally occurring conservation and changes in system characteristics.

6. Free ridership.

7. Measurement uncertainty.

8. Changes in system characteristics.

9. Balancing the convenience of using *ex ante* measurements against increased accuracy and transaction costs associated with *ex post* measurement.

2.2 Report Objectives

There is a substantial body of knowledge and established methodologies that deal with the measurement of savings from energy efficiency programs. These existing practices can provide insight regarding many of the questions raised by the Secretariat to the Board about crediting GHG emissions reductions to energy efficiency programs. The practices have been developed and implemented over a period of nearly 30 years by experts including engineers, statisticians, economists, survey researchers, utility executives, regulators and policy experts. The information presented in this report draws on this experience in order to provide guidance on high-level issues in end-use energy efficiency impact evaluation through review of existing energy efficiency programs and industry standard evaluation approaches. The advantages and disadvantages of these approaches will be discussed and reviewed in this report in the context of key technical and policy criteria.

One topic of special interest is the implications of program level measurement versus project level measurement (programs being made up of a large number of individual projects). End-use energy efficiency tends to produce relatively small reductions at the individual project level, but can yield impressive levels from large scale programs (programs being made up of a large number of individual projects). Most of the approved CDM methodologies for evaluating GHG reductions from energy efficiency focus on project level measurement, although recently approved small scale project methods do introduce concepts suited to program level activity.

In order to achieve GHG savings from energy efficiency, program level activity is necessary, together with measurement techniques suited for large-scale programs. Further development of guidelines to facilitate measurement and verification of energy efficiency programs would enhance opportunities for capturing those reductions. In program-level measurement, a sample of sites is evaluated directly, and the results are modified statistically to develop an accurate representation of the results from the program population. This report shows how impact evaluations of energy efficiency programs develop reliable energy savings estimates with acceptable uncertainty limits, at reasonable transaction costs, without requiring project level measurement.

Another important issue to consider in developing streamlined methodologies for energy efficiency under CDM is that until very recently, energy efficiency measurement focused on energy (kWh, therms) and demand (kW) savings. Emissions reductions, including GHG reductions have been considered a co-benefit, but have not always been explicitly measured or estimated. Several methodologies and protocols for estimating GHG savings as a function of energy efficiency (and to a lesser degree, demand) savings have been developed, although standardization of analysis methodologies will be important.

2.3 Report Approach

The research presented in this report has been fashioned to achieve five key objectives defined in the Terms of Reference. The specified tasks are listed below and will be addressed in the following sections as indicated.

i. Prepare a bibliography of the energy efficiency program literature, specially relating to measurement, monitoring and verification of energy reductions. (Section 3 and Appendix A).

ii. Undertake development of criteria to select the energy efficiency programs for review, in discussion with the secretariat. (Section 4).

iii. Undertake development of a framework for analysis of the EE programs identified in (ii) above, covering issues of estimating reductions, monitoring and verification procedures and any other that may be relevant. (Section 4).

iv. Review the EE programs identified in (ii) above as per the framework in (iii) above. The analysis will provide a summary at the end of key good practices followed and how these practices ensure reductions in energy consumption are real. (Section 5).

v. Conduct an analysis of how key issues, such as free riders, gross to net adjustment, etc are made in the EE programs and how they are reviewed to ensure real reductions in energy consumption. (Section 6).

Conclusions drawn from this research will be discussed, together with recommendations for next steps. (Section 7). The annotated bibliography is contained in Appendix A, and a Glossary of Terms in Appendix B.

Energy Efficiency Program Approaches and Key Evaluation Strategies

The beginning of this Section provides an overview of end-use energy efficiency program types and evaluation categories. Then fundamental components of impact evaluation are described. The section concludes with an overview of a selected bibliography prepared for this report (and located in Appendix A). The bibliography covers current energy efficiency program and evaluation literature, including references that explore extending existing evaluation practices to quantifying GHG emissions reductions. This Section of the report responds to the Terms of Reference, Task 1.

Information presented in this Section draws primarily from a recently published energy efficiency evaluation guideline prepared for the U.S. Environmental Protection Agency. The reader is encouraged to review this document for further information.[14] Another valuable evaluation guidebook was published by the International Energy Agency in 2005.[15] Additional resources are discussed at the end of this Section and in Appendix A.

3.1 Energy Efficiency Program Types

Energy-efficiency programs are planned and coordinated actions designed for a specific purpose. Programs are the engines that implement energy policy, usually set by a regulatory or governmental agency. A program's actions are usually made up of projects carried out at individual facilities, for example, replacing incandescent lighting with compact fluorescent lighting. Collectively, the outcomes of the individual projects comprise the outcome of a program, for example a utility efficiency incentive program. There are many types of energy-efficiency programs and while there is no one standard way of differentiating them, it is common to categorize program by their primary objectives. Thus, the following five categories are listed:

- Resource acquisition – primary objective is to *directly* achieve energy and/or demand savings, and possibly avoid emissions, through specific actions. All programs are designed to achieve energy savings, but resource acquisition programs focus on direct savings that are achieved quickly and are amenable to standard impact evaluation techniques.

- Market transformation – primary objective is to change the way in which energy-efficiency markets operate (how manufacturers, distributors, retailers, consumers and others sell and buy energy related products and services); which tends to result in energy and/or demand savings in a more *indirect* manner. However, to a large extent, all

[14] S. Schiller. *Model Energy-Efficiency Program Impact Evaluation Guide. National Action Plan for Energy Efficiency,* U.S. Environmental Protection Agency. 2007. http://www.epa.gov/cleanenergy/pdf/evaluation_guide.pdf
[15] H. Vreuls. *Evaluating Energy Efficiency Policy Measures and DSM Programmes, Volume I: Evaluation Guidebook.* International Energy Agency and SenterNovem. 2005.

programs can be considered market transformation in that they involve changing how energy-efficiency activities take place in the marketplace.

- Codes and standards – primary objective is to define and enforce mandated levels of efficiency in buildings and products.
- Education and training – primary objective is to inform consumers and providers about energy efficiency and encourage them to act on that information.
- Multiple objectives – objectives can include some or all of the above listed objectives.

3.1.1 Direct Effects and Indirect Effects

Programs typically produce both direct and indirect effects, both of which can be studied and evaluated, depending on informational needs. Producing savings directly means that the link between the program activity and the savings is clear, straightforward, relatively fast, and is suited to standard impact evaluation techniques – characteristics that are emphasized in resource acquisition programs. Typical examples include rebate programs to facilitate the installation of efficient equipment instead of standard equipment.

Market transformation, information, education, marketing, promotion, outreach, codes and standards or other types of similar efforts are examples of programs that aim to achieve energy savings through indirect impacts. Savings obtained from these programs depend upon inducing some form of behavior change (such as turning off lights, independently purchasing and installing efficient equipment, changing stocking or manufacturing practices to promote energy efficient measures). For these programs, there can be a more tenuous link between the program activities and any eventual savings, and thus the impacts are more difficult to estimate. However, well-designed indirect approaches can produce effects in a wide group of market actors less expensively than resource acquisition approaches, so they are an important component of any comprehensive program portfolio.

3.1.2 Focus on Impact Evaluation in this Report

All program types share the common goals of increasing the efficient use of energy and in reducing energy use. This report focuses on techniques for evaluating energy savings, and reductions in GHG emissions; thus most of the material presented here will refer to impact evaluation of resource acquisition programs or the direct savings components of other program types. If the primary objective of a program is providing savings indirectly (such as through a market transformation program), then the primary evaluation effort would most likely not be an impact evaluation (but perhaps a market effects evaluation); although an impact evaluation could still be conducted to quantify any direct savings that may be achieved. This may be particularly true when there are overlapping programs, where an education program works in tandem with a resource acquisition program to convince customers to participate and then actually incent their participation.

3.2 Energy Efficiency Evaluation

Evaluation involves assessing the performance and implementation of a program. M&V is another term often used when discussing analyses of energy-efficiency activities. M&V refers to data collection, monitoring and analysis activities associated with the calculation of gross energy and demand savings from *individual sites or projects*. M&V can be a subset of program impact evaluation. Thus, generally speaking, the differentiation between evaluation and project M&V is that evaluation is associated with programs and M&V with projects. M&V is often a component of evaluation. The term evaluation, measurement and verification, EM&V, often seen in evaluation literature, is a catchall acronym for the activities undertaken to determine both program and project impacts.

There are several basic types of evaluations as described in the following bullets. These can be undertaken to assess a variety of program results, and often a single research project combines aspects of one or more types of evaluation to answer relevant questions about the program. Evaluations are generally termed *ex-post*, or after the fact, in that they measure and analyze what has already occurred. (Sometimes evaluations, particularly process evaluations, are conducted concurrently with program operation in order to study program implementation issues.) Evaluations typically include some use of *ex-ante* data and analysis performed before project completion to predict savings. Evaluation approaches are in part tailored to the type of program being evaluated, and in part determined according to the information that is necessary to assess, report the results of or improve the design of the program.

3.2.1 Basic Evaluation Types

The three main types of evaluations are:

- *Impact evaluations* determine the impacts (usually energy and demand savings) and co benefits (such as avoided emissions, health benefits, job creation, and water savings) that directly result from a program. All categories of energy-efficiency programs can have impact evaluations however, impact evaluations are most closely associated with resource acquisition programs even though they are conducted for other programs to determine their directly-induced savings.

- *Process evaluations* assess how efficiently a program was or is being implemented, with respect to the program's stated objectives, and what lessons can be learned for future programs. All energy-efficiency program categories can have process evaluations.

- *Market effects evaluations* estimate a program's influence on encouraging future energy-efficiency projects because of changes in the marketplace. All categories of programs can have market effects; however these evaluations are primarily associated with market intervention programs that indirectly achieve impacts and resource acquisition programs that are intended to have long-term effects on the marketplace. For example, if the goal of the evaluation is to assess cost-effectiveness for stakeholders or regulators, excluding the measurement of market effects in a resource acquisition program could result in under or over-estimating the overall benefits of a program as well as its cost-effectiveness.

3.2.2 Additional Evaluation Types

There are several other common types of evaluation. Cost-effectiveness analyses can be conducted for any program which produces outcomes that can be measured and monetized, and for which program costs have been accurately tracked. Evaluations of market transformation, codes and standards, and education and training programs are based on the tenets of impact, process and market effects evaluation, but have unique characteristics and measurement strategies suited to the different program approaches.

- *Cost-effectiveness evaluations* document the relationship between the monetary value of program outcomes (energy savings and co-benefits) and the costs incurred to achieve those outcomes. It is used to determine whether the energy-efficiency program is a cost-effective investment as compared to other programs and/or energy supply resources. The cost-effectiveness analyses are typically seen as an extension of impact evaluations, but may also take into account market evaluation results considering market penetration over the expected life-time of the measures.

  The value of co-benefits of energy efficiency such as reduced transmission costs and reduced emissions can be estimated, in addition to non-energy benefits (NEBs) of the programs. NEBs can include items like water savings and reduced operations and maintenance costs, as well as non-market goods, such as job creation and improved comfort and safety. However, non-energy benefits can also be negative. Examples of negative NEBs are possible aesthetic issues associated with compact fluorescent bulbs or increased maintenance costs due to unfamiliarity with new energy-efficient equipment. Often these positive (or negative) NEBs are identified in an evaluation but the monetary value is not quantified. This is primarily because of the lack of standardized methods for monetizing these benefits, and the sense that the majority of financial benefits are associated with saved energy costs and co-benefits closely associated with reducing energy use (e.g., reduced generation and transmission costs and avoided emissions).

- *Market transformation program evaluations* tend to be a combination of impact, process and market effect evaluation and can also include cost-effectiveness evaluations. However, given that the ultimate aim of market transformation programs is to increase the adoption of energy efficient technologies and practices, market transformation evaluation is usually focused first on energy-efficiency adoption rates by market actors and secondly on the directly associated energy and demand savings. Market transformation programs are dynamic, and thus the nature of market effects can be expected to vary over time. Evaluation of market transformation interventions tends to focus on the behavior of market actors, and on the mechanisms through which changes in adoptions and energy usage are ultimately induced. This means that considerable attention must be focused on indicators of market effects through market tracking. Changes in sales patterns and volumes for particular efficiency products as an indication of program progress in meeting program goals are often examined and reported.

- *Codes and standards program evaluations* assess the impacts of the market adoption and decision changes caused by the new, modified or better enforced codes or standards and then adjust those savings to account for what would have occurred if the code or standard change or enforcement did not occur. The evaluation must identify the net energy impacts that can be directly attributed to the program's actions that would not have happened over the course of the normal, non-program influenced operations of the market. For example, analysis of a new appliance standard would involve (a) estimating the life-cycle savings associated with each new appliance placed into service as compared to a standard practice or old-standard appliances, (b) multiplying those savings by the rate over time that the new appliances are placed into service, and (c) adjusting the resulting savings estimate by the number of high-efficiency appliances that consumers would have purchased even if the standard was not in place.

- *Education and training program evaluations* focus on documenting the degree to which the programs are achieving the desired effects within the markets targeted by the program, which is educating and training people on energy efficiency. The primary mechanisms for this type of evaluation are surveys and focus groups. These evaluations tend to measure outcomes such as the number of customers reached, awareness and recall of program messages, actions taken as a result of the program, and so forth. In some instances estimates are made of the energy saved by the program, based on the number of energy efficient actions or installations participants undertake as a result of the education or training.

3.3 Overview of Impact Evaluation

The focus of this report is on impact evaluation of programs designed to achieve energy savings and concomitant GHG emissions reductions. This section introduces a few details about the mechanics of impact evaluations. Standard impact evaluation techniques are most straightforward in the context of direct resource acquisition programs where information on what equipment was installed, where it is located, and the characteristics of the standard, non-efficient equipment that would have been installed without the program is readily available in program records. Impact evaluation can also be conducted for programs that primarily produce indirect results – the core concepts are the same, however information about the measures or actions taken as a result of the program are not directly recorded and must be estimated using surveys or other techniques.

The core steps for any impact evaluation are to 1) determine gross savings, the savings that occur as a result of program operations, and 2) convert the gross quantity to net, the savings that are net of what would have occurred without the program's operation.

1. *Determine gross program energy and demand savings.* Gross savings are the impacts that occur in program participants (and in the case of spillover, some non-participants) of after participating in or being exposed to a program. Gross savings are usually developed through a combination of engineering analysis, site inspections, performance data, and energy use records for a sample of representative projects.

2. *Convert gross program savings to net energy and demand savings.* Net savings are the portion of gross savings that are directly attributable to a program, and take into account the projects that would have occurred regardless of the program's operation (termed free riders), as well as the additional savings that occurred outside of the program's

administrative framework (spillover). A free rider project would be termed non-additional in CDM terminology. Net-to-gross factors are developed through surveys and interviews of program participants and non-participants, or are stipulated based on similar programs and populations.

3.3.1 Impact Evaluation Equations and Terms

All evaluations of energy efficiency programs rely on estimates of what would have occurred had the program under review not operated, called the *base-case* or *baseline*. Since energy savings, that is: the absence of usage, cannot be measured directly, evaluation studies can only report estimates of program impacts. Estimates are based on statistical inference and always include a level of uncertainty. The procedures for conducting impact evaluations include tested procedures for minimizing and reporting uncertainty. Approaches to accounting for uncertainty due to systematic and random errors in evaluation reports are described in many of the references listed in the bibliography (Appendix A).

Key parameters for impact evaluations are typically measured *ex post*. However, impact evaluations inevitably build on existing *ex ante* information and often use stipulated values for key independent variables that drive measure savings, or stipulate the per unit savings value for a well-defined measure. *Stipulated* or *"deemed"* estimates are an efficient way to administer and evaluate mature technologies for which there is an established record of consistent savings and/or other data inputs.

The fundamental impact evaluation equations are:

Equation 1
Gross Energy Savings = Program-reported Savings X Realization Rate

Where:

Program-reported Savings are those reported by the program's administrators as documented in their records.

Equation 2
Net Energy Savings = Gross Energy Savings X Net-to-Gross Ratio

Net-to-gross ratio (NTGR) is the ratio of net savings to gross savings. The most commonly evaluated components of a net to gross ratio are free ridership and spillover, where:

NTGR = (1 – Free Rider) X (1 + Spillover)

The data required to conduct an impact evaluation follow from the independent variables in the equations presented above. Below is a brief description of each independent variable and how they are handled in an evaluation framework.

Program-reported Savings. Impact evaluations nearly always start with the program-reported savings. Just as an auditor reviews an organization's financial records and makes adjustments as necessary to report actual financial condition, so must an impact evaluator start with a program's record of activity and installations, including savings performance. The savings quantities can be *ex-ante* estimates, stipulated based on engineering analysis or prior experience, the result of M&V activities conducted for each project, or a combination of approaches.

Realization Rate. Realization rates, which allow the application of statistical sampling techniques to determine a program's true savings impact, also rely on accurate book keeping so that the evaluator can test the accuracy of the savings for representative projects. The program record must describe the baseline equipment and condition, the independent variables that determine energy usage (for example, hours of operation, load factors, temperatures), and the replacement equipment or strategy. Due to sampling error, realization rates are reported with uncertainty bounds. The uncertainty carries through to the calculated gross savings.

Free Rider. The program should document how free riders are handled. As with realization rates, program records must be accurate and complete because the evaluator will survey a sample of the program's projects in order to independently estimate free ridership factors. If present, free ridership is a critical parameter to try to measure because it can result in an over reporting of program savings. Free ridership is reported as a point estimate; its uncertainty cannot be statistically determined. Identifying free-riders, that is, participants who would have purchased energy efficiency equipment or undertaken other actions to increase efficiency in the absence of the program is becoming increasingly difficult and controversial. This is because in an environment where multiple programs operate, and where people receive encouragement and messaging from multiple sources promoting energy efficiency, it is difficult if not impossible to attribute the decision to implement energy efficiency to the influence of a single program.

Spillover. Spillover, like free ridership, is determined through surveys and interviews. Because spillover can occur not only among program participants but also non-participants, the survey audience must include all customers who may have been influenced by the program. Impact evaluation protocols for individual programs may restrict or forbid the reporting of additional savings due to spillover.

Net-to-Gross Ratio (NTGR). NTGR represents the ratio of program net savings to gross savings, taking both free-ridership (which reduces gross estimates) and spillover (which increases gross estimates) into account.

3.3.2 Calculation of Avoided Emissions from Energy Efficiency

Avoided GHG emissions are calculated by either (a) applying emission factors (e.g., pounds of CO_2 per MWh) to net energy savings or (b) using emissions scenario analyses, e.g., using computer models to estimate the difference in emissions from grid-connected power plants with and without the reduced electricity consumption associated with an efficiency program. A variety of approaches can be used to calculate emission factors or prepare scenarios analyses ranging from just using annual average emission factor values to preparing detailed hourly calculations of displaced energy sources. However, whether emissions are actually avoided depends on whether the energy savings are truly additional to what would have occurred without the efficiency activity's influences, whether all significant emissions sources associated with a program were taken into account, and the scheme under which any affected emission sources may be regulated.

3.4 Bibliography of Energy Efficiency Program Evaluation Literature

A specification of the Terms of Reference for this report is the preparation of a bibliography of energy efficiency program literature, particularly relating to the evaluation of energy savings. The bibliography is introduced next, and the full contents are included in Appendix A.

Procedures for evaluating and reporting verified program energy savings are well established, having evolved during the past thirty years into a body of knowledge agreed to and shared by researchers, regulators, equipment vendors, and private and public energy service companies and providers. The literature associated with energy efficiency programs is therefore mature and extensive. Quantifying GHG emissions reductions resulting from energy efficiency projects and programs may require extending current impact evaluation procedures; however, the existing foundations will likely guide and support such extensions.

Impact evaluation is generally considered to apply to energy efficiency (and demand reduction) programs, which are comprised of collections of individual activities conducted at the end-use customer level, for example replacing an old but operational boiler with a more efficient unit. While impact evaluation is concerned with the aggregate or program effect, it is dependent on accurate measurement and verification at the project level. Protocols and methods have been developed for both program-level and project-level accounting, and these are referred to collectively by the catch-all phrase “evaluation, monitoring and verification,” or EM&V.

However there is a clear demarcation between program level impact evaluation and the measurement and verification of savings at a project level. The reason for this distinction is simple; while we can theoretically perform measurement and verification on all individual activities performed under a program, the transaction costs can negate the value of the achieved savings. It is therefore common to apply project-level measurement and verification to a representative sample of program participants (and sometimes, non-participants for comparison) in order to perform a program-level impact evaluation. For example, in assessing a programmatic replacement of 500,000 incandescent bulbs with compact fluorescents, an impact evaluation would typically use measurement and verification protocols and apply engineering analysis and survey results to a representative sample of installations in order to develop a statistical model of the total program savings. The references cited in the bibliography can apply to impact evaluations (for programs), measurement and verification (for projects), or both, and their applications are noted when the distinction is not obvious.

The bibliography is organized into three sections as follows:

i. *Protocols and Guidelines*. These are basic, general references that are frequently cited as part of the specifications for any impact evaluation study. Protocols are general in nature and not program specific. Their use requires developing program-specific program specifications.

ii. *Program Specifications & Evaluations*. This section contains program manuals and design documents for energy efficiency programs. If applicable, M&V specifications that must be adhered to by program participants are also referenced. Where available, impact evaluation reports for each of the programs are also listed. Additional impact evaluation resources and reports are also listed here.

iii. Additional papers and Websites. The references in this section supplement the previous listings, either by exploring issues specific to certifying emissions reductions due to energy efficiency, or providing access to general resources connected to energy efficiency, impact evaluation, M&V, and GHG reductions due to efficiency.

The goal in describing the impact evaluation process is to summarize how energy efficiency programs quantify their savings impacts, and provide a sense of the basic methodologies that can be used to estimate savings and associated GHG reductions from energy efficiency programs. In Section 5, a sampling of existing energy efficiency programs and evaluation requirements will be described. The selection criteria and framework for analysis for specific programs described in this report are described next in Section 4.

Program Selection Criteria, Selected Programs, and Framework for Analysis

As one step in their plan to create a more enabling environment for energy efficiency in CDM, the Board seeks to review impact evaluation strategies used by existing energy efficiency programs. This Section describes the criteria used to select programs for review, the programs selected, and the intended framework for analysis of the selected programs. This Section responds to the Terms of Reference, Tasks 2 and 3.

4.1 Program Selection Criteria

The programs to be reviewed in this report have been selected for the purpose of providing insight regarding the manner in which they address the impact evaluation issues of concern to the Board. Mature and programs and regulatory systems offer the most complete perspective on these matters, and therefore program maturity was an important driver for the identification and selection of programs for review. Programmatic energy efficiency has been a focus of several regions in the U.S. for nearly 30 years. These systems offer comprehensive approaches to program implementation and, most importantly, impact evaluation. Furthermore, the regulatory agencies that sponsor these programs have undertaken to make substantial portions of their impact evaluation information available for public review. For these reasons, the programs selected for review in this report are primarily based in the U.S.

In order to assure that the review contains information regarding evaluation policies from other areas, programs from several other countries have been selected for review. Although the impact evaluation information available for these programs may be somewhat less complete, it offers important insight to the relative emphasis on a variety of measurement issues in different parts of the world.

4.1.1 Selection Criteria

The following criteria were employed in order to select the energy efficiency programs, and in particular, the evaluation strategies reviewed in this report. Most of the criteria relate to substantive issues that can shed light on the Board's concerns regarding impact evaluation issues. The selection criteria are:

1. Program Maturity

    - Focus on mature programs
    - Several less mature programs for comparison.

2. Program Scale

    - Focus on large scale programs
    - Several smaller scale programs for comparison.

3. Diversity of Program Types

- Focus on programs with many different program types
- Several programs with a smaller number of program types for comparison
- Emphasis on programs suited to impact evaluation.

4. Maturity of evaluation guidelines

   - Focus on programs with mature evaluation guidelines
   - Several with programs with less mature guidelines for comparison
   - Emphasis on approaches to impact evaluation.

5. Regional and cultural diversity

   - Several programs from the U.S.
   - Several from Europe and Asia.

6. Availability of documentation

   - Focus on programs with adequate and available documentation suitable for use in this report.

4.1.2 Programs selected for review

7. United States - Energy efficiency programs implemented for the California Public Utilities Commission via California's four investor-owned utilities: Pacific Gas and Electric Company, San Diego Gas & Electric, Southern California Edison and Southern California Gas Company.

8. United States - New York State portfolio of energy efficiency programs operated by the New York State Energy Research and Development Authority under the direction of the New York Public Service Commission.

9. United States - Oregon suite of energy efficiency programs ordered by the State legislature and operated by the Energy Trust of Oregon.

10. United States - Texas energy efficiency programs operated by the State's investor-owned utilities as directed by the Public Utility Commission of Texas.

11. United States - Vermont energy efficiency programs operated by Efficiency Vermont, the administrator established by the State legislature.

12. Non U.S. – Summary of eight programs reviewed in the International Energy Agency's report *Evaluating Energy Efficiency Policy Measures and DSM Programs; Volume II, Country Reports and Case Examples Used for the Evaluation Guide Book.*[16]

4.2 Framework for analysis

A framework for reviewing existing state of the art end-use energy efficiency programs, in particular, impact evaluation guidelines has been developed for this report. This framework provides the vehicle for a succinct review of existing programs; in particular, mechanisms for evaluation of energy savings since the methods for measuring energy savings serve as the basis for analyses to determine GHG reductions

The framework is designed for the purpose describing existing programs, and their impact evaluation practices, in a clear, concise format. Since the programs selected for review have been developed in different regions, with different areas of focus and for a variety of regulatory purposes, the available data are not generally consistent across programs. Thus, the framework for analysis in this report groups the subject matter into four broad categories designed to provide information that will be useful for the Board's purposes. The goal of this analysis is to provide a sensible overall description of the programs, impact evaluation strategies and areas of special interest or importance for decisions relevant to CDM. However, the specific details provided in each category vary, in some cases substantially, between programs. The non-U.S. program descriptions are arranged in a slightly different format which is more accommodating to the available data.

Details regarding the programs selected for review are summarized for comparison across the four primary framework dimensions outlined below. A description of the type of information that is included in each of the analysis categories should not be interpreted as an indication that the individual pieces of information are readily available, current or directly comparable for the programs reviewed in this report.

Note that many of the organizations sponsoring energy efficiency are also involved with promoting renewable energy, efficient transportation, water conservation and sometimes other activities. This grouping is highly variable between jurisdictions. This report focuses only on the end-use energy efficiency activities and evaluations as they are implemented in each of the selected areas.

The four categories constituting the framework for analysis of end-use energy efficiency programs discussed in this report are:

1. Program Description

[16] H. Vruels, 2005.

Information included in this section includes a program overview, and may contain details regarding program history, maturity, goals, regulatory framework and the sponsoring agency or agencies.

2. Program Size
   This section includes information related to the program budget, and may include information related to timeframe, program cycle, and achievements (MWh, MW, therms, GHGs).

3. Program types
   A description of the program activity or activities is provided, including to the extent possible, the targeted sectors, customers end-uses.

4. Impact Evaluation Processes
   Available information is summarized regarding the overall approach to evaluation, regulatory requirements, current evaluation protocols or guidelines, budgets, and key issues including, to the extent possible, discussion regarding:
   i. Reviewers
   ii. Requirements for rigor, uncertainty
   iii. Additionality
   iv. Program boundary
   v. Timeframe for analysis
   vi. Data quality and infrastructure
   vii. Gross savings
   viii. Net savings, free-ridership, technical degradation
   ix. Retention
   x. Estimation of GHG reductions
   xi. Cost-effectiveness

Program descriptions are presented in Section 5, with discussion and analysis of the results in Section 6, and conclusions in Section 7.

Program Descriptions

Section 5 provides a high level summary of five U.S. energy efficiency programs and a brief review of representative programs in eight other countries, with an emphasis on how they quantify their savings impacts. This Section responds to Task 4 in the Terms of Reference.

While the procedures and approaches used to conduct impact evaluations are well established, as described in Section 3, individual programs face unique circumstances that require selective use or modification of the available tools. The programs reviewed here demonstrate the use of both universal approaches and individual solutions to local policies or markets. Note that in some cases, energy efficiency programs are implemented by the same entities operating renewable energy programs or transportation efficiency programs. Since program implementation, and in particular, the evaluation methods are quite different for these approaches to reducing consumption of fossil fuels, this report focuses on end-use energy efficiency and only the end-use energy efficiency programs are described below.

The broad outlines of impact evaluation processes are fairly standardized, building on a record of several decades. In the United States, California leads the development of evaluation protocols and procedures, which are then often subscribed to by other states and administrative agencies. This section therefore leads off with a detailed description of the California programs. New York State programs evaluations, which borrow and modify many of the California protocols, are then described in similar detail. The remaining three US programs, all of which share the same approaches to evaluation studies, are outlined in lesser detail. Finally, case examples of European and Asian evaluations prepared by the International Energy Agency are summarized. Impact evaluation experience outside of the US is in some instances a less well-developed practice. This report focuses on US programs because direct impact evaluation is most relevant to CDM's immediate goals and the authors' research and the input received from others in the international efficiency community indicate that at least on the subject of efficiency evaluation, the U.S. has the most established track record.

Table 1: Characteristics of Selected Programs

	Program Maturity	**Scale**	**Program Scope**	**Evaluation Maturity**	**Documentation Availability**
U.S. – California	30 plus yrs	$667 M USD/yr	Comprehensive	30+ years	Extensive
U.S. – New York	9 yrs	$175 M USD/yr	Comprehensive	9 years	Extensive
U.S. – Oregon	6 yrs	$43 M USD/yr	Comprehensive	5+ years	Limited
U.S. – Texas	5 yrs	$80 M USD/yr	Comprehensive	1 report	Moderate
U.S. – Vermont	7 yrs	$25 M USD/yr	Comprehensive	7+ years	Limited
Non – U.S.	Varies	Varies	Varies	Varies	Varies

5.1 United States – California Public Utilities Commission

5.1.1 Program Description

The California Public Utilities Commission (CPUC) has been providing for energy efficiency programs in California for nearly thirty years. The programs are implemented through the state's four investor-owned utilities which are subject to regulation by the CPUC. Together, these four utilities serve approximately 80 percent of California residents, about 27 million people. The programs are supervised by the CPUC with the assistance of the California Energy Commission (CEC). The CPUC directs the utilities to offer the programs, approves the overall budgets, program portfolio and evaluation requirements, and supervises the utilities throughout all phases of the program planning, implementation and reporting cycle. Funding is derived from a "public goods charge" on customers' utility bills, which provides for energy efficiency and low income programs.

In the beginning, the utilities calculated the results of their programs through *ex ante* engineering estimates. By the early 1990s the utilities were required to rely more on *ex post* measurement than engineering. Because of its long history of program evaluation, California's measurement practices have pioneered methods to address complex issues, and the evaluations have become increasingly sophisticated over the years. Although programs in other states or regions have their own requirements for evaluation, many of them borrow heavily from the CPUC program evaluation experience.

5.1.2 Program Size[17]

Energy efficiency spending has grown steadily since the inception of the programs, and has been dramatically increased in recent years. The budget for the current three year funding cycle, 2006-2008, is more than $2 billion USD. The projected impacts from these programs include 6,800 GWh in reduced annual electricity consumption, 1,000 MW in peak demand reduction, and 111 million therms of natural gas savings. This will enable California to avoid the equivalent of three large (500 megawatt) power plants. Approximately 8 percent of the budget, $175 million USD, is allocated for evaluation. Most of the evaluations are designed to measure program impacts, though other aspects of the programs are studied as well. Other evaluations include evaluations of market transformation programs, codes and standards programs, emerging technologies, market assessments, and special research designed to improve forecasting parameters such as measure life or technical degradation.

[17] California Public Utilities Commission. Ruling 06-04-010. 01-02-07. http://www.cpuc.ca.gov/EFILE/RULINGS/63295.pdf

5.1.3 Program types

Each utility offers a set of programs, called a "program portfolio" and all of the utility programs together constitute the overall CPUC program portfolio. The CPUC allocates funding to the utilities based on the goals developed for each utility service territory. The goals are informed by studies that estimate the potential for capturing cost-effective energy savings, building on information such as building types and vintages, existing equipment, appliances and so forth. Using this information it is possible to estimate the savings that are available and the costs for improving efficiency.

The utilities serve as administrators for the programs, primarily by soliciting bids from a number of private companies to implement the work. The utilities are responsible to the CPUC for overseeing the work conducted by private companies, organizing the overall portfolio of program offerings, advertising, requiring appropriate inspections and quality assurance, and continuously reporting accomplishments to the CPUC.

The programs are designed to enable residential, business and governmental customers to take advantage of a diverse mix of energy efficiency and conservation activities. Examples include information/education, energy audits, rebate and direct installation of energy efficient measures, market interventions, demonstrations, emerging technologies analyses, design assistance and codes and standards promotion. Also in the list are financing strategies, sustainable communities programs, and integrated offerings to targeted markets. Some program strategies include partnerships with local governments, universities and schools.

5.1.4 Evaluation, Measurement and Verification (EM&V)

Like the CPUC system for administering the program portfolio itself, the rules governing program evaluation are elaborate and have become increasingly sophisticated over the course of 30 years. The current program evaluation protocol is 278 pages in length. Further instructions are articulated in a number of regulatory documents and proceedings.[18,19]

The program evaluation planning process begins with a high-level assessment of the need to evaluate a program or program component. The CPUC determines which programs require each type of evaluation in order to estimate overall savings. This assessment considers, among other factors, the importance of the savings to the portfolio and the uncertainty regarding the ex-ante savings estimates, input from program administrators, direction from the regulatory staff and elapsed time since prior reviews.

[18] TecMarket Works. *California Energy Efficiency Evaluation Protocols: Technical, Methodological and Reporting Requirements for Evaluation Professionals.* California Public Utilities Commission. 2006.

[19] Note the CPUC Protocols are intricate and complex. Information in this section has been extracted and summarized for relevance to this report.

5.1.4.1 Reviewers

The evaluations are conducted by professional evaluation firms. Until recently, the evaluation firms were hired and supervised by the utilities implementing the programs and reviewed by a consultant team reporting to, and working with the CPUC. In addition, other key stakeholders such as representatives from the CEC, regulatory agencies and nonprofit groups would also participate on review committees. However, a few years ago the CPUC decided that they will hire and supervise the evaluators.[20]

5.1.4.2 Requirements for rigor, uncertainty

The requirements for rigor vary according to the pre-determined evaluation needs for each program. Evaluators must conduct a power analysis to estimate the required sample size, and to estimate the uncertainty in deemed and measured input parameters, considering sources of error and sample sizes necessary to meet the required error tolerance levels. They may also consider prior evaluations for similar programs and use professional judgment to determine an appropriate and achievable level of rigor for the analysis.

In most cases, evaluators are expected to use a combination of deemed and measured data sources with sufficient sample sizes to meet a 30 percent error tolerance level in the reported value at a 90 percent confidence level. From a statistical perspective, this means that there must be a 90 percent chance that the reported results are within 30 percent of the actual value. Note that there is an equal probability that the actual results could be either lower or higher than the estimates reported by the evaluation. Some programs require greater rigor, and the evaluations must meet a 10 percent error tolerance level with 90 percent confidence.

5.1.4.3 Program boundary

The boundary for the overall CPUC program portfolio includes the service territories of each of the four investor owned utilities. The boundary for each of the utility portfolios is set according to the service territory of that utility. There is an emphasis on having consistency on the large programs so that application processes, rebate levels, etc. are consistent between the different utility service territories. Some smaller scale programs options vary between service territories. A few of the programs, those that are formed as partnerships with local governments or educational districts, operate only within specific boundaries defined by the local government or district.

In most cases the evaluation analyses are conducted within the relevant service territory. However, in instances where there is evidence that program effects occur beyond these boundaries, evaluation may be required to estimate the impacts. For example, there has been some indication that when participants received rebates for efficient refrigerators, the replaced refrigerators were being shipped out of the territory but were still in use. In this case, evaluations were necessary to determine the extent of this problem, and the programs were revised to include

[20] The CPUC now hires the impact evaluators, the utilities still hire and supervise process evaluators.

provisions that the old refrigerators would be decommissioned in order for participants to receive a rebate.

5.1.4.4 Timeframe for analysis

Evaluations are scheduled for several timeframes throughout the program period, and following program implementation, allowing sufficient time for post-implementation data to be collected and *ex post* evaluation to occur. In order to ensure that the programs are on track, several parameters, in particular, measure installations, are tracked and reported during program implementation, using *ex ante* estimates of savings. *Ex post* evaluations that require extensive data analyses, for example those that include 12 months of pre- and post- retrofit energy consumption, may take up to two years after the end of the program to complete.

Once evaluation results have been delivered, reviewed and approved, savings for the expected lifetime of the measures installed as a result of the programs are credited. Different measures have different lifetimes, and the overall portfolio results include the sum of the lifetime savings for all of the measures installed during the program period.

5.1.4.5 Data quality and infrastructure

The CPUC program implementation and evaluation processes require *ex post* evaluation, but inputs to the ex post evaluation include many sources of ex ante data in addition to the post-implementation measurements. The CPUC programs make use of an extensive and well-developed data infrastructure including detailed *ex ante* savings estimates for thousands of energy efficiency measures, operating in a number of building types and sectors that have different operating hours, in a variety of conditions including different weather zones. These data have been developed originally from engineering estimates, and revised via *ex post* evaluations conducted over many years. Where *ex post* program evaluation results are judged to be superior to the *ex ante* estimates for a particular program, sector, and/or measure, the most current *ex post* results become the new *ex ante* estimates for the next program cycle. Through this system of feedback, the *ex ante* estimates become increasingly reliable over time.

5.1.4.6 Gross savings

All impact evaluations must be planned, conducted, analyzed and reported to minimize potential bias in the estimates, justify the methods selected for doing this and report all analysis of potential bias issues. Appropriate baselines must be selected based on a variety of factors that constitute business as usual in the absence of program impacts. The baseline is important in both the gross and the net impact calculation.

Statistical, econometric, and engineering analysis of energy consumption data must address outliers, missing data, weather adjustment, selection bias, background variables, data screens, autocorrelation, truncation, error in measuring variables, model specification and omitted variable error, heteroscedasticity, collinearity and influential data points.

Engineering analysis and M&V based methods are required to address sources of uncertainty in parameters, construction of baseline, guarding against measurement error, site selection and non-response bias, engineering model bias, modeler bias, deemed parameter bias, meter bias, sensor placement bias and non-random selection of equipment or circuits to monitor.

Evaluations must assess, plan, measure and incorporate background and change variables that might be expected to be correlated with gross and net energy and/or demand savings. Comparison groups must be carefully selected with justification of the criteria for selection of the comparison group and discussion of any potential bias and how the selected comparison group provides the best available minimization of any potential bias.

5.1.4.7 Net savings, free ridership, technical degradation

Net-to-gross ratios are developed for each of the programs and/or program delivery strategies as part of the impact evaluations. In some cases, the net-to-gross ratios are also reported for specific measures and or end-uses associated with a given delivery strategy, as appropriate. In some cases, the net-to-gross ratios are stipulated *ex ante*, typically in cases where the existing values are determined to be current, accurate and applicable.

The design of the overall research must address baseline issues that arise in either or both the gross and net impacts calculations. The degree to which the research design, selected method, survey instrument design, question wording and model specification can reliably capture this underlying construct is the evaluation's construct validity. These elements must work together and must be justified based upon how well they address construct validity.

All participant net impact analysis must be designed to estimate the proportion of savings that is program-induced and net of free-ridership. Participant and non-participant analysis of utility consumption data that addresses the issue of self-selection into the programs, since those who choose to participate may have different savings profiles than non-participants.

Methods for assessing free-ridership may include self-reporting and other data sources relevant to the decision to install/adopt. These other data sources could include, for example, record/business policy and paper review, examination of other similar decisions, interviews with multiple actors the end-user site, interviews with mid-stream and upstream market actors, analysis of typically built buildings (as opposed buildings with efficient measures) and/or vendor and manufacturer stocking practices. As a rule of thumb, surveys conducted to estimate for free ridership via self-report are required to have a minimum sample size of 300 participant decision-makers for at least 300 participant sites (where decision-makers may cover more than one site) or a census attempt, whichever is smaller.

Technical degradation is included as a multiplier used to account for time- and use- related change in the energy savings of a high efficiency measure or practice relative to a standard efficiency measure or practice due to technical operational characteristics of the measure, including operating conditions and product design. In many cases, studies have shown that efficient measures actually last longer and perform better then standard counterparts. In these cases the technical degradation factor is positive for the efficient measures.

It is important to note that the issue of how net to gross ratios are calculated and the implied attribution of responsibility for savings results has become quite controversial in California, with an increasing perception that determining net savings directly attributable to a particular program in a complex market with multiple influences on energy efficiency activities is quite difficult if not impossible.

5.1.4.8 Additionality

Impacts of energy efficiency programs in California are based on *net* energy, demand and therm savings. The term *net* in energy efficiency is essentially the same concept as *additional* in the context of avoided emissions. Net savings means the savings that are directly related to program activities, having taken effects such as free ridership and baseline energy use into consideration – the savings would not have occurred in the absence of the program. Note that spillover can also be measured. Spillover includes savings attributable to the programs that occur above and beyond direct program impacts.

5.1.4.9 Retention

Measure retention is defined as the length of time that measures installed via the programs are in place and operable. Assessing retention over the lifetime of installed measures is expensive and time consuming, involving periodic inspections of a panel of installed measures over the course of several years. Beginning in the 1990s, the CPUC initiated a number of measure retention studies occurring periodically over a period of up to nine years. Due to the complexity and cost of retention research, most current evaluations rely on measure retention estimates developed in earlier studies.

5.1.4.10 Estimation of GHG reductions

The cumulative energy savings of the 2006-6008 programs will reduce emissions by an estimated 3.4 million tons of CO_2. To date, GHG impacts are calculated at a very high level, using relatively simple techniques to estimate GHG reductions as a function of net energy savings from the portfolio. Processes are underway to develop more sophisticated techniques using dispatch models that take account of the timing of energy savings and differences in the energy mix on the grid by season and at different times of day.

5.1.4.11 Cost-effectiveness

The CPUC programs rely on benefit-cost tests outlined in the California Standard Practice Manual. The tests assess costs and benefits from several perspectives, including the ratepayer, program administrator, overall society, and total resources. A slightly different arrangement of benefits and costs are included in each test, depending on the perspective of those paying costs and receiving benefits. The Total Resource Cost Test (TRC) serves as the primary indicator of energy efficiency program cost effectiveness, consistent with the view that ratepayer-funded energy efficiency should focus on programs that serve as resource alternatives to supply-side options. The TRC test measures the net resource benefits from the perspective of all ratepayers by combining the net benefits of the program to participants and non-participants. The benefits are the avoided costs of the supply-side resources avoided or deferred. The TRC costs encompass the cost of the measures/equipment installed and the costs incurred by the program administrator. The TRC is calculated utilizing a discount rate that reflects the utilities' weighted average cost of capital, as adopted by the CPUC. A small adder for emissions savings that occur as a result of the programs is also included.

5.2 United States – New York State

5.2.1 Program Description

Energy efficiency programs in New York State are funded by a surcharge levied on most of the State's retail electric customers as initiated by the New York State Public Service Commission in 1998. The surcharge, formally known as the System Benefit Charge (SBC), was extended and increased in 2001 and again in 2005. As part of the order establishing the SBC, the Commission named the New York State Energy Research and Development Authority (NYSERDA) as administrator of the SBC funds, with directives that they be managed to:

1. Improve system-wide reliability and peak reduction through end-user efficiency actions.

2. Improve energy efficiency and access to energy options for underserved customers.

3. Reduce environmental impacts of energy production and use.

4. Facilitate retail electric competition to benefit end-users.

NYSERDA, as the SBC administrator, designed, launched and now operates the **New York Energy $mart**SM Program, to meet the Commission's directives. **New York Energy $mart**SM is an umbrella program and marketing brand name for a portfolio of more than forty SBC-funded programs that target all retail electric customer types and sectors, as well as most common energy using systems and devices. Most **New York Energy $mart**SM customers receive electric power from investor-owned utilities, and the utilities and NYSERDA are therefore independently serving the same customer base.

Approximately 53 percent of program funding is earmarked for implementing energy efficiency and peak load reduction projects in the commercial, industrial, and residential sectors; another 23 percent is set aside for improving energy efficiency in the low-income, residential sector; the balance funds energy and environmental research and development programs. In addition the program funds small renewable energy and combined heat-and-power installations.

5.2.2 Program Size

Ex-post evaluation studies estimate that as of December 2006 **New York Energy $mart**SM is saving New York State ratepayers 2,460 GWh per year of electric energy and reducing the system peak load demand by 1,113 MW. These impacts are the result of installations supported by the program since its debut in 1998. NYSERDA, which promotes the program to most of the State's 19,300,000 residents, can take credit for installations counted in the hundreds of thousands ranging in size from residential compact fluorescent lamp replacements to the construction of 40 MW of wind power. In addition, NYSERDA estimates that as of year-end 2006 **New York Energy $mart**SM has reduced CO_2 emissions by 1.6 million tons per year due to avoided power generation.

The **New York Energy $mart**SM budget for the 2006 – 2011 cycle is $895.9 million USD, or about $175 million USD/year. Of this, about 90 percent is reserved for program implementation, 8 percent for administration and overhead, and 2 percent for evaluation.

5.2.3 Program Types

Because NYSERDA is charged with meeting multiple objectives and required to serve all rate payers, **New York Energy $mart**^{SM} programs employ the following different strategies:

- Market transformation, seeks to develop markets and to change consumer energy-related decision making to improve energy efficiency.
- Energy efficiency, actively intervenes in the market to reward consumers to use energy efficiency equipment and operating strategies.
- Load management, rewards consumers to shift electric load and energy use from on-peak to off-peak periods.
- Low income, targets low income households with the goal of reducing their energy cost burden through the installation of energy efficiency improvements.
- Research and development, supports the development and deployment of emerging alterative energy products and strategies, including the construction of demonstration projects.

In practice individual programs often incorporate two or more of these strategies to achieve multiple goals. For example, the Enhanced Commercial/Industrial Performance Program, which accounts for approximately one third of the portfolio electric energy savings, is an energy efficiency program that also seeks to build the infrastructure to support energy efficiency offerings.

5.2.4 Evaluation, Measurement and Verification (EM&V)

EM&V is an integral part of all programs in the **New York Energy $mart**^{SM} portfolio and methods for quantifying project and program savings are outlined in the program design phase. All programs maintain tracking databases to record key installation and market information needed to prepare status reports, and to support *ex-post* impact evaluation reviews. NYSERDA depends on a network of contractors and consultants for support in designing and operating the programs in the **New York Energy $mart**^{SM} portfolio. NYSERDA typically remains the point of contact for each program, and thus maintains administrative control, and is the final authority when making strategic or programmatic decisions.

The NYSERDA evaluation process is unusual in that review teams are organized by discipline (e.g. impact, process, market assessment) rather than by customer type or sector, the more common practice. NYSERDA employs specialty contractors to perform the reviews, but retains overall management authority. The independence and integrity of the evaluation team is protected by the oversight by representatives of the Public Service Commission, and by the review of a committee of stakeholders, the System Benefit Charge Advisory Group, convened to guide the administration of the SBC funds.

NYSERDA evaluation planning methods differ from the detailed, mandated procedures specified in California. At the beginning of each program year, the evaluation teams plan review activities for the coming twelve months. Study needs are identified on the basis of the previous year results, input from program administrators, direction from the Public Service Commission staff and the System Benefit Charge Advisory Committee, program size, and elapsed time since prior reviews.

5.2.4.1 Reviewers

NYSERDA uses a competitively selected team of professional firms specializing in the evaluation of energy efficiency programs. The contractors prepare NYSERDA's impact and process evaluations, and conduct market research. In an attempt to integrate evaluation reviews and report results with a portfolio perspective, contractors are selected by discipline (impact, process, theory and logic) rather than by program type. Consequently, each contractor is responsible for reviewing all **New York Energy $mart**^{SM} programs, an approach intended to result in uniform treatment and analysis of savings and economic performance.

5.2.4.2 Requirements for rigor, uncertainty

Impact evaluation studies are planned to report findings with 20 percent precision at the 80 percent confidence level. This standard has evolved over a number of evaluation cycles, and was set by the evaluation contracting team largely in response to available funds. Gross impact evaluation activities include site inspections to verify equipment installation and operation for a random selection of completed projects. Fixed per unit inspection costs combined with limited funding result in small sample sizes and the 80/20 criteria.

5.2.4.3 Program boundary

**New York Energy $mart**^{SM} operates only in New York State serving the customers of the State's investor owned electric utilities. Thus the spatial boundary for all impact evaluation studies is well defined.

5.2.4.4 Timeframe for analysis

Impact evaluation results are reported on a cumulative annual basis (kWh/year) and accounts for the effect of all operational projects completed in any program year. Results for program energy savings are also summed for all years of operation and reported as the cumulative program impact (kWh/program). Both of these metrics, kWh/year and kWh/program, depend on accurate and complete accounting records maintained by NYSERDA. In a small number of cases incomplete files have prevented reporting individual program impacts.

Impact evaluation studies are conducted on a ranked list of programs selected by factors such as time since previous study, high uncertainty in earlier study results, size of program, innovative nature of program, or other factors. In practice, major programs contributing to the bulk of **New York Energy $mart**^{SM} reported savings are evaluated every two to three years.

5.2.4.5 Data quality and infrastructure

Impact evaluation reviews are dependent on *ex-ante* estimates of savings for specific technologies and devices, M&V results for individual projects in many large programs, and accurate record keeping of all program participants. NYSERDA maintains reasonably complete records for **New York Energy $mart**^{SM} and is able to support evaluator requirements for accurate information.

NYSERDA recognized early problems with tracking and archiving the data needed to conduct impact evaluations and produce reliable results. Through a coordination of implementation administrators and evaluation teams, NYSERDA has improved its data record in the past few years. Recent program designs have included extensive and detailed requirements to support future evaluations. In addition, NYSERDA has built new Web-based databases that cover groups of program types, such as commercial or residential.

5.2.4.6 Gross savings

Gross savings are generally developed using realization rates calculated for a representative sample of completed projects. The available budgets have constrained their accuracy to 20 percent precision at the 80 percent confidence level, though the cumulative result of multiple studies may permit a higher level of accuracy in the future.

Evaluators conduct engineering reviews of the savings reported for the sample of selected projects. Assumptions and key independent variables are noted, and these are checked during site visits to verify the installation and operation of the measures included in the projects. The data record is checked for agreement with the individual project reports. The impact evaluators adjust the reported savings at each step to account for any discrepancies, and the result is the verified savings in the realization rate calculation. Adjustments are also made to normalize weather influences, production rates, occupancy levels and other variables that can influence energy consumption in buildings and industrial facilities.

For programs designed to influence distributors and retailers to promote energy efficient alternatives to the market standard, as has been done with appliances, lighting and motors, the impact evaluator reviews the engineering analysis that underlies the per unit savings values used by NYSERDA in calculating program savings. Where possible, the evaluators will also inspect installations to verify operating assumptions, though with no direct customer contact this is the exception rather than the rule. Numbers of installations are determined through surveys and reports from the participating distributors and retailers.

New York Energy $martSM uses deemed savings[21] values for some mature technologies where the unit savings can be estimated with confidence for well defined applications. Examples are replacing residential incandescent lighting with compact fluorescent lighting, or motor replacements in certain HVAC or industrial process applications. The unit savings and their basis are warehoused in NYSERDA's *Deemed Savings Database*. For programs using deemed savings, the gross savings are taken from the *Deemed Savings Database*. The database is under continuous review by the impact evaluator.

[21] Deemed savings values are developed through engineering analysis and past experience or M&V results for specific technologies or measures. The savings are then stipulated for each application of measure. When a customer receives a cash incentive for installing one of the measures, the incentive amount is typically based on the value of the stipulated savings.

In general, gross savings use a standard practice baseline, typically the codes and standards in force at the time of replacement.

5.2.4.7 Net savings, free ridership, technical degradation

The NYSERDA evaluation team calculates a net-to-gross ratio, and net savings, by measuring and adjusting for free ridership and both participant and non-participant spillover. The data for these factors is obtained primarily through surveys of randomly selected customer pools.

5.2.4.8 Additionality

The net savings reported by NYSERDA for the **New York Energy $mart**^{SM} Program are additional.

5.2.4.9 Retention

**New York Energy $mart**^{SM} has assumed retention based on surveys conducted by other energy efficiency programs and engineering studies; there has been little primary research conducted within New York State to determine local measure lives. The secondary data sources most widely cited by the program are California's *DEER Database*, Efficiency Vermont's Technical *Reference User Manual*, and effective useful life studies conducted by the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

5.2.4.10 Estimation of GHG reductions

NYSERDA reports NO_X, SO_2 and CO_2 emissions reductions for avoided energy generation based on the impact evaluation results for **New York Energy $mart**^{SM}, assumed avoided transmission and distribution losses, and Statewide emissions factors. The reported reductions are reasonable estimates of program co-benefits, though there is a recognized need to improve the methodology if greater accuracy is warranted.

5.2.4.11 Cost-effectiveness

NYSERDA determines program cost-effectiveness using the Total Market Effects Test (TMET) and the Program Efficiency Test (PET), following the California Standard Practice Manual. The TMET compares life-cycle energy benefits (cost savings) against costs incurred by both customers and NYSERDA. The PET compares the same life-cycle benefits against only NYSERDA's costs.

Each test is conducted using four scenarios, in which each scenario includes an additional benefit attributable to the program. Additional benefits beyond energy cost savings include, energy price market effects (reduction in wholesale electric prices due to reduced load), non-energy benefits (health, safety, change in productivity), and macro-economic impacts at the State level.

5.3 United States -- Energy Trust of Oregon[22]

5.3.1 Program Description

Energy Trust of Oregon, Inc., began operation in March 2002, charged by the Oregon Public Utility Commission with investing in cost-effective energy conservation, helping to pay the above-market costs of renewable energy resources, and encouraging efficiency market transformation in Oregon. Energy Trust funds come from a 1999 energy restructuring law, which required Oregon's two largest investor-owned utilities to collect a three percent "public purposes charge" from their customers. The law also dedicated a separate portion of the public-purpose funding to energy conservation efforts in low-income housing energy assistance and K-12 schools.

The law authorized the Oregon Public Utilities Commission to direct these funds to a non-governmental entity for investment. Energy Trust was organized as a nonprofit organization for this purpose. In addition to its work under the 1999 energy restructuring law, the Energy Trust administers gas conservation programs for residential and commercial customers of NW Natural (starting in 2003) and Cascade Natural Gas Corporation (starting July, 2006), and select programs for residential customers of Avista Corporation (September, 2006) in Oregon.[23]

Energy Trust programs are managed by a small staff, with the majority of programs delivered by specialized service providers who represent a network of over 750 business trade allies from around the state. Two advisory councils lead the work, together with a volunteer board of directors. The work is conducted under contract to the Oregon Public Utility Commission which sets minimum performance requirements.

5.3.2 Program Size

In 2006, the Energy Trust spent $43.2 million USD on energy efficiency, yielding 289 annual MWh, 33.1 MW of energy savings, and 2.2 million therms. Nearly 300,000 Oregonians were assisted by 2006 programs.

The evaluation budget is approximately 2-3 percent of the overall annual budget, which includes funds for both energy efficiency and renewable energy. Most of the evaluations are related to the energy efficiency programs although some research is also conducted on the renewable programs.

5.3.3 Program Types

The Energy Trust offers residential utility customers opportunities to take advantage of energy-saving recommendations, referrals to qualified contractors and cash incentives for qualified improvements including insulation to duct sealing, electric and gas water heaters, furnaces and

[22] Information in this section is drawn from the Energy Trust of Oregon website, www.energytrust.org .
[23] Energy Trust of Oregon. 2006 Annual Report. Energy Trust of Oregon, Inc. 2007.

heat pumps. Other programs include energy efficiency improvements targeting multifamily and manufactured dwellings and a web-based Home Energy Analyzer to help customers learn how they can improve the efficiency of their residences.

Programs for business customers include a range of electric and gas energy-saving services and incentives for existing commercial and institutional facilities. Incentives are offered for qualified improvements such as lighting, heating, ventilation and air conditioning, motors, controls, natural gas space and water heaters, restaurant equipment, insulation and manufacturing processes. The Energy Trust also offers services including energy surveys and technical analysis, contractor referrals, project facilitation and post-installation assistance. Business customers can also take advantage of rebates for high efficiency electric and gas equipment, energy modeling and design assistance to help maximize efficiency of new construction projects, major renovations and additions to existing buildings, and building tune ups to maximize the efficiency of existing facilities.

5.3.4 Evaluation, Measurement and Verification (EM&V)

The Energy Trust commissions impact, process and market effects evaluation studies on an ongoing, annual basis. The studies are carried out by independent contractors selected through a competitive bidding process.

The Energy Trust does not use a set of pre-specific evaluation protocols or guidelines. Rather, the evaluations are required to be conducted at high levels of rigor given current professional practices, and as supervised and reviewed by recognized experts in the field. Impact evaluation reviews are dependent on ex-ante estimates of savings for specific technologies and devices, M&V results for individual programs that account for the largest share of savings. Reviews can also be ordered in areas where *ex ante* estimates are determined to be in need of updating.

5.3.4.1 Reviewers

Evaluation staff at the Energy Trust decides which evaluations will be conducted and reviews and supervises the research in consultation with members of their Board and selected experts. The evaluations are conducted by independent energy efficiency evaluation contractors.

5.3.4.2 Uncertainty/requirements for rigor

The evaluations are designed with the evaluation budgets in mind, aiming to achieve 90 percent certainty that the estimates are within 10 percent of the true value of energy saved by the programs. Evaluation activities are focused on programs or areas that are expected to account for at least 50-80 percent of energy savings, and/or where additional information about the program or program inputs is needed.

5.3.4.3 Program boundary

The Energy Trust programs are available to customers of the sponsoring utilities, which cover all but the southeast corner of Oregon.

5.3.4.4 Timeframe for analysis

Each program is evaluated annually, although the focus and extent of the evaluation varies according to research priorities. Savings estimates are developed for the lifetime of measures installed as a result of the programs.

5.3.4.5 Data quality and infrastructure

The Energy Trust program implementation and evaluation processes use *ex post* evaluation, but take advantage of many sources of *ex ante* data as inputs to the program planning process and evaluations. Data sources are obtained from the Oregon's Regional Technical Forum as well as from industry sources and other parts of the country (for example, California's DEER Database. As with evaluations conducted in most systems, modifications are made to *ex ante* data inputs as needed, to adjust for building and equipment vintage, weather and other conditions suited to the program territory and evaluation needs. *Ex ante* estimates are revised to incorporate *ex post* evaluation results over time, so that the *ex ante* estimates become increasingly accurate and reliable.

5.3.4.6 Gross savings

Gross savings estimates are developed according to industry standard practices, following the same procedures described in earlier sections of this report, for example, California and New York. There are no specific protocols or guidelines that must be followed, but the research is supervised, conducted and reviewed by industry experts.

5.3.4.7 Net savings, free ridership, technical degradation

Net savings estimates are developed according to industry standard practices, following the same procedures described in earlier sections of this report, for example, California and New York. Evaluations assess net savings including spillover, market effects, and other aspects of program infrastructure or implementation that have been designated for study in a given evaluation cycle. There are no specific protocols or guidelines that must be followed, but the research is supervised, conducted and reviewed by industry experts.

5.3.4.8 Additionality

Net energy savings are reported, which is equivalent to additional savings as that term is used in terms of climate change.

5.3.4.9 Retention

Retention estimates are currently developed from existing data sources, and modified as necessary by professional judgment to adjust for factors such as building turnover. Some retention studies for specific measures are being planned for the near future.

5.3.4.10 Estimation of GHG reductions

The 2006 programs reduced CO_2 generated by fossil fuels by an estimated 213,000 tons. The estimate was developed as a function of energy savings, using high level assumptions to convert savings from efficiency to emissions reductions.

5.3.4.11 Cost-effectiveness

The Energy Trust uses benefit-cost test similar to those in the California *Standard Practice Manual*. Several tests are conducted, assessing benefits and costs from several perspectives. The costs include program and avoided generation costs, non-energy benefits "as quantified by a reasonable and practical method." There is a 10 percent credit for energy efficiency as required under the Northwest Power Act.[24] This credit recognizes the benefits of conservation in addressing risk and uncertainty. There is an adder of $15.00 USD per ton of CO_2 reduced, and the cost of carbon can be updated as information improves.

5.4 United States – Texas

Energy efficiency programs in Texas are operated by the six investor-owned electric utilities serving the majority of the State's electricity consumers. The programs were ordered as part of a legislative action restructuring the State's retail electric markets.

5.4.1 Program Description

Texas Senate Bill 7 passed in 1999, which opened Texas electricity markets to limited retail access, mandated that the States six major electric utilities operate energy efficiency programs to achieve demand reductions equal to 10 percent of forecast load growth. The utilities' programs began pilot operations in 2002 and opened to full-scale operations in 2003. As authorized by the restructuring regulations, funding for the programs is provided by rate payers.

Recent legislation has raised the energy efficiency goal to 15 percent of forecasted load growth in 2008 and then 20 percent in 2009.

5.4.2 Program Size

In 2005, utility expenditures were approximately $80 million USD. Ninety percent of funds are required to be spent on incentives and promotions; the remaining ten percent is reserved for administration, including the M&V of savings. During the same period, the programs resulted in a peak demand reduction of 181 MW and achieved 509 GWh in energy savings. Since beginning operations in 2002, the programs have reduced peak demand by 592 MW and are saving 1,639 GWh per year.

Since 2002, the programs have exceeded their mandated savings targets; in 2005 the demand reduction was twenty seven percent above the goal.

5.4.3 Program Types

Senate Bill 7 charged the Public Utility Commission of Texas with establishing the framework for carrying out the bill's order. During 2000 and 2001, the Commission developed templates for eight programs. The templates lay out the framework of each program, with each utility developing its own administrative structure.

The programs are either of the standard offer or market transformation type. Market transformation programs pay a fixed price for each kWh and kW of savings delivered by a contractor to the program. The largest of these is the Commercial / Industrial Program which

[24] Energy Trust of Oregon Board of Directors. Energy Trust of Oregon, Inc. 2005.

pays for savings from energy efficiency retrofits in existing facilities. Market transformation programs seek to bring about permanent change in the market by promoting energy efficiency alternatives. The largest market transformation program is the Texas **Energy Star**® New Homes Program, which supports builders constructing **Energy Star** homes and conducts education campaigns to create customer demand.

The programs target commercial and industrial, residential, and low-income customers.

5.4.4 Evaluation, Measurement and Verification (EM&V)

The utilities are required to file annual reports documenting the savings achieved during the prior year. However, Texas does not require the same extensive, independent, ongoing impact evaluation review found in the California and New York programs. Instead the State relies on the M&V requirements embodied in the program templates and the administrating utilities to ensure accurate savings reports from their contractors. In addition, a number of programs use deemed savings values that have been developed independently for the Commission.

5.4.4.1 Reviewers

As noted, the Commission does not require systematic and periodic impact evaluation studies. However, in 2005 the Commission hired an independent evaluator to conduct a desk audit of the energy demand savings reported by the utilities for the years 2003 and 2004. The evaluation found that the savings filed for those years were under reporting by approximately two percent, thus largely affirming the accuracy of the filings.

5.4.4.2 Requirements for rigor, uncertainty

The Commission in its approved program templates does not specify accuracy requirements for savings reports, nor did it prescribe targets for the one evaluation study conducted to date.

5.4.4.3 Program boundary

The Texas energy efficiency programs are available only to in-State customers of the sponsoring utilities.

5.4.4.4 Timeframe for analysis

As noted, sponsoring utilities are required to file annual reports with the Commission documenting savings performance for the prior year. There has been only one retrospective evaluation review since 2002 and it was limited to 2003 and 2004.

5.4.4.5 Data quality and bookkeeping infrastructure

The sponsoring utilities have developed databases used to administer the programs, including payments, savings, and application processing. According to the 2005 evaluation, the databases were found to be accurate, and were judged to be a key element in the efficient administration of the programs.

5.4.4.6 Gross savings

The utility sponsors report gross savings based on their records for each project's performance, generally determined during its first year of operation.

5.4.4.7 Net savings, free ridership, technical degradation

The Texas programs only report gross savings but generally assume that they are equal to net savings; to date no research has been conducted to measure free ridership, spillover, or persistence. The 2005 evaluation report recommends that these activities be undertaken.

Free ridership, while not measured, was addressed in the design of the program templates where lists of ineligible measures, some judged to have the potential to generate free riders, were included.

5.4.4.8 Additionality

Assuming that the net to gross ratio for the Texas programs is close to one, the savings reported to the Commission are *net* and therefore *additional*, as these terms are equivalent.

5.4.4.9 Retention

To date no retention studies have been conducted in Texas.

5.4.4.10 Estimation of GHG reductions

The utilities and the Commission do not report any GHG reductions that might be due to the programs.

5.4.4.11 Cost-effectiveness

The ordering legislation and the rules promulgated by the Commission require that the energy efficiency savings be cost-effective. The rules stipulate avoided capacity and energy costs. Measures are screened for their cost-effectiveness as part of the program design phases and the project application stage, but to date no formal retrospective cost effectiveness study has been performed.

5.5 United States -- Vermont

5.5.1 Program Description

Efficiency Vermont provides energy efficiency services to the state of Vermont. It was created in 2000 and is operated by an independent, non-profit organization under contract to the Vermont Public Service Board. The organization is funded by an energy efficiency charge on electricity bills in the service territories of several Vermont utilities. Prior to the establishment of Efficiency Vermont, individual utilities in the area provided energy efficiency services. Now, most residents receive services from Efficiency Vermont, although one utility in the state, Burlington Electricity Department, still handles programs for its own customers.

5.5.2 Program Size

In 2006, Efficiency Vermont helped 38,655 Vermonters, more than 10 percent of the state's electric ratepayers, complete efficiency investments that resulted in:

- $5.7 million USD in annual electric, fuel and water savings.

- 56,000,000 kWh of annual electric savings.

- A 10,000 kW reduction in summer peak and a 9,000 kW reduction in winter peak capacity requirements.

5.5.3 Program Types

Efficiency Vermont provides technical assistance and financial incentives to Vermont households and businesses, to help them reduce their energy costs with energy-efficient equipment and lighting and with energy-efficient approaches to construction and renovation. It also works with Vermont businesses that provide energy-efficient products and services, including retailers, architects, builders, and electricians. Efficiency Vermont also organizes and sponsors a well known annual conference on building efficiency and value.

5.5.4 Evaluation, Measurement and Verification (EM&V)

The Vermont Department of Public Service contracts with a number of qualified firms and individuals to provide an independent evaluation of Efficiency Vermont's management and delivery of the core, state-wide programs in Vermont. The program evaluation activities are coordinated closely with primary research conducted to better understand and characterize the specific markets and market participants targeted by the core programs. The evaluations have three main purposes:

- Verification of the annual savings and total resource benefits claimed by Efficiency Vermont (and Burlington Electric Department) for each year of the 3 year periods.

- Assessment of energy efficiency markets and establishment of baselines to better document the market and the effects of the programs on those markets, including lost opportunities.

- Assessment of non-residential, commercial and industrial energy efficiency markets to better document market conditions and the effects of the programs on those markets.

The formulas and values used to calculate gross and net savings using a modified engineering estimate approach are agreed upon in advance by Efficiency Vermont, Department of Public Service staff and the Contract Administrator, and are recorded in a lengthy and comprehensive document called the *Technical Reference Manual*.[25]

5.5.4.1 Reviewers

Evaluation staff at the Vermont Public Service Department reviews and supervises the evaluations, in consultation with selected industry experts hired to support the effort. The evaluations are conducted by independent energy efficiency evaluation contractors.

[25] Efficiency Vermont. *Technical User Manual No. 2006-43*. Efficiency Vermont, Inc. 2007.

5.5.4.2 Uncertainty/requirements for rigor

There are no specific requirements for rigor, although industry professionals conduct and review the analyses in order to ensure their quality and accuracy. The statistical accuracy of each impact evaluation is described in the individual reports.[26]

5.5.4.3 Program boundary

Efficiency Vermont serves all Vermont residents except those who live in the Burlington Electric Department's service territory, where that utility provides energy efficiency services.

5.5.4.4 Timeframe for analysis

Each program is evaluated annually, with a summary report prepared for every three year program cycle. Savings estimates are developed for the lifetime of measures installed as a result of the programs. The average measure life is currently 13 years.

5.5.4.5 Data quality and infrastructure

Most of the engineering values and adjustment factors in the initial (2000) version of the *Technical Reference Manual*, were developed from *The Power to Save: A Plan to Transform Vermont's Energy-Efficiency Markets,*[27] a feasibility study. The report, issued by the Vermont Department of Public Service in May of 1997, includes analyses of the potential energy and capacity savings from a variety of energy efficiency programs and technologies. The data and assumptions underlying these analyses, including engineering values and adjustment factors, are contained in appendices and associated work papers. The engineering values and adjustment factors are derived from manufacturer specifications and from studies conducted by Vermont utilities and energy efficiency programs in other states. Annotations and footnotes in the *Technical Reference Manual* cite the sources for many, but not all, of the engineering values and adjustment factors.

5.5.4.6 Gross savings

Efficiency Vermont's energy and capacity savings estimates for standard energy efficiency measures are prepared on a measure-by-measure, program-by-program, basis using modified engineering estimates. The calculations for each measure include gross customer electric savings without counting the effects of line losses from the generator to the customer, free-ridership, spillover, or persistence. The estimates do not distribute the savings among the different costing periods. All energy and capacity savings estimates are based on a comparison of the energy efficient version of the project to a base case representing the project as it would have been implemented in the absence of the program. When customers have already prepared initial project plans before they are contacted by for participation, the base case is straightforward. In other cases, equipment vendors are able to provide information on the types

[26] A recent study called for common approaches for evaluation protocols in the Northeast United States. Northeast Energy Efficiency Partnerships, Inc. *The Need for and Approaches to Developing Common Protocols to Measure, Verify and Report Energy Efficiency Savings in the Northeast*. Northeast Energy Efficiency Partnerships, Inc. 2006.

[27] Vermont Department of Public Service. *The Power to Save: A Plan to Transform Vermont's Energy-Efficiency Markets.* Vermont Department of Public Service. 1997.

of equipment ordinarily included in a "standard bid." Where these sources of information are not available, the base case is usually assumed to be the minimum code standard. This is a common method used by energy efficiency programs across the nation.

5.5.4.7 Net savings, free ridership, technical degradation

Gross energy and capacity savings estimates are adjusted downward by a free ridership factor that is determined individually for each measure in each program to account for program participants who were planning to install energy efficient measures even in the absence of the program. Gross energy and capacity savings estimates are adjusted upward by a spillover factor that is determined individually for each measure in each program. The spillover factor is the converse of the free ridership factor. It accounts for the likelihood that an energy efficiency program is responsible for some purchases of energy efficiency measures that never show up in the program's tracking system. There are no specific protocols or guidelines that must be followed, but the research is supervised, conducted and reviewed by industry experts.

5.5.4.8 Additionality

Net energy savings are reported, which is equivalent to additional savings as that term is used in the context of climate change.

5.5.4.9 Retention

Retention estimates are incorporated into the measure life estimates referenced in the *Technical Reference Manual*.

5.5.4.10 Estimation of GHG reductions

The Efficiency Vermont programs in 2006 reduced CO_2 generated by fossil fuels by an estimated 415,300 tons over the lifetime of the measures. The estimate was developed as a function of energy savings, using high level assumptions to convert savings from efficiency to emissions reductions.

5.5.4.11 Cost-effectiveness

Efficiency Vermont programs are assessed with several cost benefit tests. The Utility Cost Test is a commonly used benefit/cost analysis tool, which estimates the annualized cost to the sponsoring utility per kWh of electricity saved by its programs. The inputs to the test are the annualized MWh savings from Efficiency Vermont programs, Efficiency Vermont's actual program expenditures, and the average lifetime of the energy efficiency measures installed. The Societal Cost-Benefit Test is a broader measure of program cost-effectiveness. It seeks to summarize and compare all the costs and benefits of the program, regardless of who pays the costs or receives the benefits.

The following costs are included in the Societal test: [28]

[28] Cummings, M. *Independent Audit of Vermont Energy Efficiency Utility Energy and Capacity Savings for 2002 Through 2004.* 2005.

- Program costs - including any rebates or incentives paid to participants and performance incentives paid to Efficiency Vermont.

- Participant costs – mainly the measure costs paid by participants.

- Administrative costs.

The following benefits are included in the Societal test:

- Resource benefits - primarily from electric energy and capacity savings. Decreases in water consumption from energy efficient washing machines, etc. are also included in resource benefits.

- Environmental benefits of reduced generation.

5.6 Non-United States Programs – International Energy Agency Report

Although many countries have pursued energy efficiency policies, aggressively in many cases, the direct impacts of the policies and programs have not always been explicitly evaluated. The majority of systematic energy efficiency evaluation relevant to this project has been conducted in the United States. The level of detail available in documentation for evaluations conducted in countries other than the United States is less complete, and the studies are not always readily available. The International Energy Agency (IEA) produced a report in 2005 containing comprehensive case studies of energy efficiency activities, including policy measures, programs and program evaluation (where available), in eight countries.[29] This section draws upon and summarizes this research, in particular focusing on programs that have been evaluated and the evaluation strategies that were employed. The information presented in this section is in a slightly different format than the U.S. programs in order to better accommodate the available data.

5.6.1 Belgium

5.6.1.1 Approaches to energy efficiency

A number of energy efficiency policies and programs have been implemented in Belgium, although only few have been evaluated and/or well documented. Energy efficiency policy is complicated in Belgium because efficiency is handled through regional institutions while energy prices and other aspects of the market are addressed by the federal government.

Case studies of energy efficiency policies and measures covered in the IEA report cover the period 1990-2002. The activities include building codes, municipal energy centers providing information on energy efficiency and campaigns for a more rational use of energy by the power distribution companies.

[29] H. Vreuls. *Evaluating Energy Efficiency Policy Measures and DSM Programmes, Volume II: Country Reports and Case Examples Used for the Evaluation Guidebook.* International Energy Agency and SenterNovem. 2005.

5.6.1.2 Overview of evaluations

The IEA research noted that only a few of the Belgian programs and policy measures have been studied -- nine evaluations were reviewed. One of the largest programs included rebates offered by electricity distribution companies – that program was evaluated three times in a twelve year period. The IEA reports that for the most part "the evaluations have not been thoughtfully planned from the start of the programs … Therefore many data were lost and had to be estimated or extrapolated."

5.6.1.3 Energy efficiency programs

Energy efficiency programs operated by power distribution companies had a total budget of 64.6 million EU in 1996-2001 for rebates, information and training, and energy audits.

5.6.1.4 Types of impacts reported in program evaluations

Most program evaluations are limited to reporting the number of consumers reached, numbers of efficient appliances sold, etc. Most of the evaluations were conducted internally by the sponsoring organization, although two were conducted by independent evaluators. The internal evaluations focused on gross savings and costs, while the subsequent external evaluations attempted to determine net energy savings and provide more precise estimates of impacts and costs.

Two evaluations discussed in the IEA report incorporated baseline assessments. Six evaluations reported estimated energy savings, four reported GHG emissions reductions, and one reported cost-effectiveness. The evaluation that assessed net energy savings did so by taking into account the number of participants, estimated energy saved per sold appliance, free rider effects and rebound effects.

5.6.2 Canada

5.6.2.1 Approaches to energy efficiency

Canada has been promoting energy efficiency initiatives since the 1970s, and is now relying heavily on efficiency to meet its commitments under the Kyoto Protocol. Many of the programs and policies have been evaluated, and a sample of results from recently completed studies is included in the IEA report.

Canada's federal government has jurisdiction over standards and labeling for equipment, appliances and vehicles, while the provinces have jurisdiction over energy supply and building codes. The IEA report primarily profiles policies and programs offered by the federal government. However, many of the provinces offer energy efficiency, typically delivered by the energy utilities or other provincial organizations. The federal government provides information and labeling, codes and standards, incentives, voluntary agreements and support for emerging technologies. The interventions target the residential, business and service sectors, including new and existing buildings. The federal Office of Energy Efficiency had a budget of $70 million CDN in 2004.

5.6.2.2 Overview of evaluations

The federal Office of Energy Efficiency is directly involved in the assessment, evaluation, monitoring and data collection of energy efficiency activities throughout the country, and specifically in those promoted by the federal government. Many assessments and evaluations have been undertaken over the years. The Office of Energy Efficiency has developed indicators, targets and other program monitoring and tracking requirements, and conducts analyses of energy and GHG reductions. Process, impact and market evaluations are conducted -- some by governmental departments and others by external evaluators.

The IEA report mentions 30 evaluations published between 1994 and 2004, noting that these are only a sample of the evaluations completed throughout the country during that period.

5.6.2.3 Energy efficiency programs

The programs described in the IEA report are primarily policy-related (codes and standards, appliance and equipment labeling) and informational programs offered by the federal government. Typical resource acquisition programs including incentives for installing energy efficient measures are common in Canada, but tend to be operated by the energy distribution companies, and are not covered in as much detail in the IEA report.

5.6.2.4 Types of impacts reported in program evaluations

The evaluations described in the IEA report typically identify a number of indicators relevant to the program process (e.g., number of participants, satisfaction, information recall), as well as program impacts in terms of both energy and emissions reductions. Twenty of the 30 studies listed reported energy savings estimates, and 18 of those studies also reported GHG emissions reductions. Energy savings tend to be estimated using similar methods to those used in the United States. In general, *ex post* evaluations are conducted to measure and refine *ex ante* savings estimates. A baseline for the analysis is developed to reflect what would have happened in the absence of the program. Gross impacts are estimated and then net savings adjustments are made, taking into account free ridership, naturally occurring changes in the market and spillover effects. Emissions reductions are calculated as a function of net savings.

5.6.3 Denmark

5.6.3.1 Approaches to energy efficiency

Denmark has committed to aggressive GHG emissions reductions, and is relying heavily on energy efficiency as a means of meeting its goals. Denmark has actively promoted energy efficiency since the 1970s. There are three main actors in the Danish system – the Danish Energy Authority, the Electricity Saving Trust and the electricity network companies. The electricity network companies initiate the majority of the work and coordinate with one another through an umbrella organization. Case studies in the IEA report include energy labeling of small buildings, codes and standards for buildings and appliances, energy management for large buildings, electricity audits and informational campaigns.

5.6.3.2 Overview of evaluations

Danish energy savings activities are typically evaluated using independent consultants. The Danish Energy Authority publishes energy savings reports regularly. These include information (thought not forecasts) on 1) actual consumption, 2) estimated consumption without improvements to demand side energy efficiency, and 3) estimated consumption without improvements that have occurred on both the supply and demand side (i.e., adjusted for economic growth).

In 2002 a handbook on evaluation of energy savings activities was developed to systemize evaluation efforts and transfer expertise from the electricity sector to the natural gas and district heat sectors. Three levels of evaluation rigor are specified, depending on the purpose of the evaluation and the type of activity being studied. Baselines are often established prior to implementation of policies or programs. *Ex post* evaluation activities are conducted, and efforts are made to distinguish net energy and emissions reduction impacts from those that would have occurred in the absence of energy efficiency activities. The Danish Energy Authority publishes guidelines and data to be used in calculating societal benefits from energy efficiency activities, and conversion factors for estimating CO_2 emissions reductions from electricity savings.

5.6.3.3 Energy efficiency programs

The budget for programs implemented by the electricity network companies in 2002 was 162 million DKK, which was collected through electricity bills. Several programs implemented by the electricity network companies were discussed in the IEA report. Energy management for large and small buildings and homes is available. The larger buildings are required by law to participate by integrating energy management systems – requirements vary for buildings of different sizes. The programs offer audits and assistance with identifying cost-effect energy savings opportunities to facilitate compliance with the regulation. The interventions also included information/education activities such as appliance labeling.

5.6.3.4 Types of impacts reported in program evaluations

Seven evaluations conducted for programs implemented by the electricity network companies were discussed in the IEA report. Five of these were informational/education programs and two promoted labeling of refrigerator/freezers and compact fluorescent lights. All seven incorporate some form of *ex post* evaluation, and contain information regarding baseline assessment, program costs, number of participants, and influence on customer decisions. Six of the seven studies reported energy and emissions reductions.

5.6.4 France

5.6.4.1 Approaches to energy efficiency

Energy efficiency has been an important component of the French energy policy since the mid 1970s. National efforts are operated primarily by a federal agency called ADEME, which is also responsible for environment-related activities such as waste management and air pollution control. New laws promoting energy efficiency and a climate plan are the primary forces in France's current energy efficiency policy. In 2003 ADEME's budget for energy efficiency was 26 million EU. National activities include information/education, audits, technology research, demonstration projects, and building codes. Case studies of informational campaigns, energy centers and audits are discussed in the IEA report.

5.6.4.2 Overview of evaluations

Beginning in recent years, the French government requires that the impacts of various programs for the public, including ADEME's energy efficiency activities, be evaluated. Even prior to this regulation, energy efficiency programs have been studied – some of the research relied on *ex post* evaluation of particular measures. ADEME reports energy and CO_2 savings from its activities by end-use and sector, annually. Through an annual survey of households, France also tracks energy consumption of all its citizens, as well as expenditures on energy efficiency.

5.6.4.3 Energy efficiency programs

ADEME programs including an information campaign, energy centers and energy audits are discussed in the IEA document. The information campaigns were designed to improve knowledge and stimulate adoption of energy efficiency among the general public – this program was implemented for four months in 2001. France has developed more than 160 local information centers which provide advice to households, building professionals, companies and other organizations. The centers operate on an ongoing basis. ADEME also offers energy audits targeted at all actors, although its primary focus is on business and industry. More than 35,000 buildings were audited over the period 2000-2006.

5.6.4.4 Types of impacts reported in program evaluations

Program results are assessed in terms of customers targeted, number of contacts, actions taken as a result of the information or audit, costs of the program as well as participant costs, market effects and estimated impacts in terms of reductions in energy use and CO_2. Studies that look at the aggregate impacts of energy efficiency activities on baseline consumption are more common than studies of individual programs or measures. The evaluations described in the IEA report estimated gross savings as compared to a baseline, but did not appear to address issues of free-ridership. Emissions savings are calculated as a function of energy savings, using information developed by ADEME.

5.6.5 Republic of Korea

5.6.5.1 Approaches to energy efficiency

Korea has implemented energy efficiency policies and programs since the 1970s in order to harmonize energy, economy and environment, and to buffer the effect of changes in international fossil fuel prices. Korea imports more than 90 percent of its fossil fuels, which makes energy efficiency a critical issue for the health of the economy. A good portion of the demand side management activities discussed in the IEA report focus on load management and peak reduction. Several energy efficiency promotions were described in the report, including energy performance standards, subsidies for efficient lighting, appliances, motors, and inverters, and energy audits. The programs are administered by the Korea Energy Management Corporation (KEMCO).

5.6.5.2 Overview of evaluations

Evaluation for energy efficiency programs is relatively new for Korea. Where programs have been evaluated, the emphasis is on output indicators and expected energy savings. More extensive evaluation activities are currently in the planning and early implementation phase.

5.6.5.3 Energy efficiency programs

The primary method for promoting energy efficiency in Korea is through minimum performance standards for a variety of products and equipment. Appliances and other products that do not meet minimum standards cannot be sold legally. There are strict guidelines for product labeling to assist buyers in purchasing preferred goods, and incentives for manufacturers that develop efficient technologies. KEMCO also conducts free energy audits for small and large buildings, with a particular emphasis on energy-intensive industries. Korea became the first non-Annex I country to commission voluntary agreements with industry to reduce GHG emissions. Companies willing to join the voluntary agreement submit a concrete action plan outlining emissions reductions targets and strategies for achieving them. If the plans are accepted, the companies receive low interest and tax incentives for energy efficiency and GHG reductions.

5.6.5.4 Types of impacts reported in program evaluations

The performance standards program has not yet been evaluated. Some data have reported for audits, including program accomplishments (number of participants, etc.) and estimated savings. Any reductions in energy use that occur after participation in an audit are attributed to the program without adjustment for possible free-ridership. Plans are underway to estimate savings attributable to energy labeling rules. However, a problem that has been noted is “snapback” -- buyers tend to be replacing older appliances and equipment with much larger models, mitigating energy savings even when the new models are more efficient.

5.6.6 Italy

5.6.6.1 Approaches to energy efficiency

Until the late 1990s, there was not a great deal of governmental effort to promote energy efficiency in Italy, although there were some activities targeted toward residential customers. Developments including concern over energy supply, increasing per capita consumption and Italy’s Kyoto commitments have greatly increased interest in energy efficiency in recent years. Earlier activities focused on codes and standards for buildings and appliances and on financial incentives. The newer approaches are comprehensive, targeting utilities, energy service companies, governments in local regions and provinces, end-users in all sectors, and different actors in the supply chain including installers, wholesalers, distributors and professional associations. Italy is also experimenting with white certificates for GHG savings derived from energy efficiency, and is supporting other projects designed to reduce emissions.

5.6.6.2 Overview of evaluations

In 2001 the legislature adopted specifications for energy efficiency program evaluation. Three evaluation approaches have been defined: 1) deemed estimates with no *ex post* measurement, 2) engineering approaches incorporating some *ex post* measurement, and 3) measurement with *ex post* monitoring. In order for projects to be certified, they must meet requirements for project design, recordkeeping, and inspections. Procedures for setting appropriate baselines have also been introduced. The evaluation described in the IEA report used engineering estimates, including building type and weather inputs, to estimate gross savings, but did not make any adjustments for free-ridership or spillover.

5.6.6.3 Energy efficiency programs

Italy has recently set aggressive national targets for reducing electricity and gas use, with savings goals increasing annually for the electricity and gas distributors. A variety of demand-side activities are being implemented, targeting all end-use sectors. Five energy efficiency programs were mentioned in the IEA report. They addressed domestic lighting and water heating, boilers, windows for residential buildings and wall insulation.

5.6.6.4 Types of impacts reported in program evaluations

Rigorous evaluation has not been a priority until the last few years. Earlier studies tended to report program accomplishments and estimated savings based on *ex ante* estimates. The new federal guidelines for reporting energy and emissions reductions require substantially increased rigor.

5.6.7 The Netherlands

5.6.7.1 Approaches to energy efficiency

The Netherlands government has been promoting energy efficiency since the 1970s. The level of effort increased significantly in the last decade, in response to policies designed to reduce energy use and GHGs. Earlier programs focused more on technologies, but now the focus is on general programs and markets. Case studies described in the IEA report include energy performance standards for residential buildings, rebates for energy efficient homes and appliances, and incentives for businesses to reduce energy consumption.

5.6.7.2 Overview of evaluations

The Dutch government has used an internal guideline for program evaluation since 1994. External evaluators typically conduct the work. At a minimum, program records are reviewed and stakeholders are interviewed. The evaluations address three main questions:

- To what extent are the goals set out in the program met?
- How was the performance of the agency carrying out the program?
- What was the market response to the program?

The evaluation guidelines describe procedures for setting baselines and conducting *ex post* evaluation. Typically, governmental programs are evaluated every four years, with some annual reporting requirements.

5.6.7.3 Energy efficiency programs

In the 1970s and 1980s, policies for energy savings in homes were implemented by increasing the requirements for roof and wall insulation, windows, etc. In the 1990s, the strategy was converted to an overall performance standard in order to give architects, developers and home owners choices about how to comply (the insulation requirements were retained). This change was supported with demonstrations and informational campaigns to educate market actors and owners about the new system. Since 1998 incentives have been available for activities designed to reduce energy use and emissions. A wide variety of measures are eligible for rebates, through programs targeted at different residential and business market segments. Appliance and equipment labeling and extensive informational campaigns are implemented to promote the programs. Also, businesses, especially those in energy intensive industries, are encouraged to enter into voluntary agreements to reduce energy use and GHG emissions.

5.6.7.4 Types of impacts reported in program evaluations

Evaluation results in the IEA report indicate that program accomplishments such as number of program participants, costs and market effects are reported, and combined with *ex ante* engineering values to estimate savings. Free ridership is evaluated as part of the assessment of market effects resulting from the programs. Energy savings and emissions reductions impacts are being included more and more frequently. GHG reductions are reported at the aggregate level rather than by program, using conversion factors for estimating emissions reductions from reduced energy use.

5.6.8 Sweden

5.6.8.1 Approaches to energy efficiency

Energy efficiency has long been an important element in the Swedish government's energy policy agenda. A number of interventions have been implemented and over time evaluation methods for energy efficiency have developed. Governmental programs initially focused on technology procurement. However, to stimulate market penetration, technology procurements have been combined with additional measures such as demonstrations, information, appliance and equipment labeling, education, incentives and voluntary agreements. Different combinations of activities are used for different technologies. The total budget for the 1991-1997 period was 950 million SEK, with approximately 3 percent allocated for evaluation.

5.6.8.2 Overview of evaluations

Several evaluations of the Swedish measures for energy efficiency have been performed over the years. Most of them have been prepared in general terms describing the program and measures. Only a few evaluations have assessed program impacts. Evaluations are conducted both internally and by external researchers. The IEA report indicates that 22 evaluations have been conducted since 1991. Data collection and follow-up activities tend to include:

- Interviews before and after activities, measuring number of consumers reached, and increase in knowledge.
- Interviews with non-participants
- Sales statistics
- Program costs
- Interviews with market actors.

5.6.8.3 Energy efficiency programs

Most of the programs implemented from 1991-1997 were based on information campaigns with incentives, and related program activities. From 1997-2002 most of the incentives were dropped and only the information, education and demonstration aspects continued. Programs described in the IEA report include information and education campaigns operated through municipal energy information centers, energy audits, standards, technology procurement and market transformation approaches.

5.6.8.4 Types of impacts reported in program evaluations

Over time, indicators reported in the evaluations have grown from simply describing technology performance and price reduction to reporting sales data, market share, changes in product mix, and changes in knowledge, attitudes and behavior of market actors, consumers and other market effects. As of 1996, published evaluation guidelines began to include information describing the effects of economic and other conditions, free-ridership ("informal standards"), and spillover. None of the 22 evaluations listed in the IEA document reported GHG reductions, and only two reported energy savings. Where they were included in the evaluation, energy savings based on *ex ante* estimates of unit savings and sales statistics.

The energy efficiency programs and M&V strategies described in this section are analyzed and discussed in Section 6.

Discussion

As evidenced in Section 5, many institutions, governments, communities and countries around the world have been implementing a variety of energy efficiency programs, policies and practices in one form or another since the 1970s. Accordingly, the programs and policies have been evaluated over time, using techniques that have become increasingly sophisticated. There is broad agreement on basic approaches to program evaluation, although the specific requirements for accuracy and techniques used vary widely between jurisdictions. Until recently there has been little need for cross-jurisdictional comparisons between evaluation requirements, so the rules and regulations governing evaluation varied accordingly. But this is changing given the importance of estimating GHG emission reductions as a benefit of efficiency, and the need for cross-jurisdictional comparison in this context, e.g. offsets under cap and trade programs.

Arguably, the style of evaluation most readily applicable to estimating GHG reductions from energy efficiency is impact evaluation as it is conducted most often in the U.S. This may be because a primary concern of U.S. regulators and energy efficiency policy has been to ensure that savings from energy efficiency can be directly compared with energy supply in terms of energy units, e.g. kWh, kW and kilojoules. Although evaluating energy impacts is an important issue whenever energy efficiency programs are evaluated, some jurisdictions and countries focus more attention on metrics such as numbers of participants reached, implementation of codes and standards, and overall energy intensity per capita. U.S. impact evaluation approaches that lead to reliable estimates of units of energy consumption reduced lend themselves to methods for estimating GHG reductions by conversion factors used to calculate avoided emissions as a function of avoided energy supply.

Not surprisingly, the most sophisticated and elaborate impact evaluations are conducted in California and New York, where expenditures on energy efficiency programs total nearly a billion US$ per year. Evaluation approaches, regulatory requirements, data availability and quality have evolved over time in order to support increasingly complex measurement. However, it is not practical or necessary to expect the same level of detail in areas that do not have the same highly developed data or regulatory infrastructure. Indeed, energy efficiency program evaluation is a field that has matured over time, and practitioners are accustomed to building and adjusting techniques to accommodate a wide spectrum of program approaches, regulatory requirements, data availability and evaluation resources. The basic tenets for impact evaluation still apply, and there is reasonably consistent professional agreement on methods for evaluating energy and emission impacts given varying programmatic, data, and regulatory circumstances.

6.1.1 Key Methodological Challenges for Energy Efficiency Project Activities under CDM

As noted earlier in this report, the Secretariat, in a note for the thirty second meeting of the Board, prepared a summary of the key methodological challenges for energy efficiency project activities under CDM. Many of the challenges involve critical questions about verifying GHG emissions reductions and their additionality. These issues are examined next, in light of lessons learned from the literature review and program descriptions presented in previous Sections. This Section of the report responds to Task 5 in the Terms of Reference.

Impact evaluations verify avoided energy usage resulting from program operations, and those energy reductions are reported as net, or additional in CDM parlance. Since verified energy savings are the analytical precursor to certified emissions reductions for energy efficiency programs, understanding the methods that the evaluation profession has developed to ensure that savings are real may help the Board in developing methodologies for programs of activities (PoA).

This section is built around the list of the Secretariat's key methodological challenges, as introduced in Section 2. Each challenge is presented, followed by a discussion of how it was handled by the energy efficiency programs detailed earlier in the report.

1. *Increasing the number of approved methodologies for end-use energy efficiency in the industrial, commercial, residential, and services sectors.*

   While the methodologies developed by the programs in Section 5 may belong to a diverse group and are tailored for local conditions, for a given technology or application their similarities generally outweigh their differences. As a result the evaluation community has a library of methodologies available to apply to the commonly deployed resource acquisition and market transformation programs.

   Administrators of energy efficiency programs[30] depend on a diffuse collection of market actors to promote, install, and maintain energy efficient equipment and strategies. In order for programs to succeed, projects must be built. As a consequence of this dependence, administrators constantly seek ways to reduce barriers that can dissuade potential customers from participating in their programs, all the while protecting the integrity of end-use savings reporting.

   Many if not all of the programs described in Section 5 have supported the development of EM&V methodologies that are tailored for individual measures and for entire programs. The approaches have been top-down and led by the administrators, or bottom-up and solicited from participants.

   As an example of the top-down approach, the Public Utility Commission of Texas convened a working group of local electric utilities and interested parties to develop program templates that led to the development of twelve program templates. In addition to covering the goals

[30] These remarks apply to resource acquisition, market transformation, and to a certain degree, education and training programs. Codes and standards initiatives, which by their nature do not allow participants to opt out, are not as dependent on methodologies for determining savings. Generally savings for codes and standards programs are estimated *ex-ante*, and are evaluated through *ex-post* surveys and/or engineering assessments.

and format of each program, they provide guidance for calculating savings from projects, including the prescribed deemed savings values in some cases.

In some programs operating in California, New York, Texas and elsewhere, a bottom-up approach encourages program participants to propose individual M&V methodologies or plans that adhere to *IPMVP* guidelines. Once approved by the program administrator the M&V plan becomes part of the operating agreement for the project, and can be replicated by other participants.

A useful reference, and one adopted by many of the programs described in Section 5, is the *FEMP M&V Guidelines* published by the US Department of Energy. This document applies *IPMVP* standards to specific measures commonly seen in building energy retrofit projects. The guidelines comprise a set of methodologies for determining savings for the covered measures.

Implicit in the examples cited above is the concept that accurate reporting at the project level will lead to accurate program reporting. Indeed, the programs cited above all depend on using approved M&V methodologies for individual projects in order to report verified program savings. Impact evaluations retrospectively assess the accuracy of the reports, they generally do not attempt to independently create reports; to do so would be inefficient, cumbersome, and most likely less accurate.

2. *Measuring energy savings and concomitant GHG reductions with adequate accuracy and precision, given the number of independent factors that may affect energy consumption that are not related to energy efficiency improvements (e.g., weather, energy prices, operation and maintenance practices.*

   While most energy efficiency programs are only now beginning to grapple with measuring and reporting GHG reductions[31], they have for many decades dealt effectively with quantifying their energy savings. There is no single approach to how this is done because different programs and jurisdictions tend to define *adequate accuracy and precision* to match the local market, and the measures promoted by the programs.

   In the regulated environment of the US electricity market, energy efficiency programs generally must report verified savings in order to maintain regulatory support. Often, from the regulator's perspective, the money spent to acquire energy savings competes with other supply-side options, and the energy savings on the demand-side needs to be more cost-effective than the supply side options. Benefit-cost analysis depends on accurate savings

[31] However, there has been significant recent activity to address this gap. Chief among these are the World Resource Institute and World Business Council for Sustainable Development *The Greenhouse Protocol*; the U.S. Department of Energy and US Environmental Protection Agency *Model Energy-Efficiency Program Impact Evaluation Guide*; and the International Energy Agency *Evaluating Energy Efficiency Policy Measures and DSM Programmes*.

data, hence the imperative for administrators to comply with regulator's accuracy requirements.

Energy efficiency programs generally rely on a small number of protocols and guidelines when dealing with changes in independent variables such as weather, occupancy, industrial production, and weather. Both the *IPMVP* and the *FEMP M&V Guidelines* provide guidance on how to make adjustments to account for changes in independent variables. These documents are incorporated in all of the U.S. programs discussed in Section 5, and the *IPMVP,* international in scope and application, is commonly referenced outside of the U.S.

Generally a discussion of accuracy and precision presumes that the variable to be reported, such as energy savings, involves sampling of the population in question[32]. To reiterate, reliable program savings depend on accurate project savings (and record keeping). In impact evaluations, *ex post* estimates of program savings use representative samples of projects to develop realization rates that are then applied to the entire population of completed projects. The results are reported along with statistics that describe the precision of the results at a given confidence interval.

Most programs listed in Section 5 define uncertainty targets for impact evaluation surveying, not necessarily the final savings value determined. For example, in most cases in California evaluation plans try to require sample selection at the 90 percent confidence level with 30 percent precision. Some evaluations require greater accuracy and are reported at the 90/10 level. In New York impact evaluation surveying is down at the 80/20 level, while Oregon uses a 90/10 criterion.

3. *Setting boundaries for the analysis.*

All of the programs reviewed in Section 5 operate within political boundaries, and so the administrators and evaluators work with populations within pre-defined geographical regions. However, it is not uncommon for a portfolio of programs operating within these regions to interact by serving the same customer or region. These cases may be analogous to the boundary problems envisioned by the Secretariat.

In New York State, discounting for cross program participation starts with accurate record keeping. As part of the impact evaluation process, customers who have participated in two or more programs are identified with search queries, and their savings are adjusted on an individual basis. For example, an audit program may have recommended to a customer certain measures that were later implemented through a separate retrofit program. Both programs may be reporting savings for this customer, resulting in a doubling of the actual

[32] Other sources of uncertainty include measurement error and modeling error. Programs in California, Texas, and New York usually define precision targets for these parameters and require that each project comply. In theory this uncertainty could be included in an impact evaluation analysis, but in practice it is usually ignored.

results. In this case the solution is for the impact evaluation team to credit the savings to one or the other programs, but not both.

It should be noted that attributing savings when projects or programs are under the control of multiple jurisdictions, sometimes with overlapping boundaries, has become increasingly problematic in recent years as the magnitude of energy efficiency efforts increases. This is most evident in California where the topic is currently under debate in the regulatory and evaluation communities.

In addition to programmatic boundaries, the M&V at an individual project will also have a measurement boundary that defines the system space to be analyzed when determining project savings. M&V boundaries can be drawn around a piece of equipment, for example a chiller, around a building, or a group of buildings on a campus. The *IPMVP*, cited in all the US programs listed in Section 5, describes how to determine where to set the M&V boundary. In some cases energy efficiency measures can inter-act with equipment outside the M&V boundary, and again the *IPMVP* provides guidance on how to measure and report these interactions. A common example of an interactive effect is the reduction in cooling load due to a lighting retrofit, which reduces chiller loads while increasing heating requirements. Some programs in Texas stipulate a cooling bonus factor and report the additional cooling savings due to lighting projects. In other US programs interactive effects are ignored on the basis that they are small (less than 10 percent) and the difficulty in measuring them.

4. *Equipment lifetime for retrofit, replacement and new construction projects.*

   The five US programs reviewed in Section 5 rely on engineering estimates and survey data compiled by ASHRAE[33] in stipulating the lifetime estimates that underlie any life-cycle assessment of energy efficiency programs. In some cases, notably California, these data are supplemented by local survey studies of actual equipment lives.

   In addition to equipment lifetimes, the expected physical life of installed equipment, impact evaluators also need to account for the degradation in savings as energy efficient equipment is replaced prior to failure, or buildings and facilities are razed. Those few programs like California that try to measure persistence rely on periodic survey studies of populations of program participants.

5. *Establishing appropriate baseline scenarios that account for historical usage, changes in operation, technology degradation and naturally occurring conservation and changes in system characteristics*.

[33] ASHRAE. *2007 ASHRAE Handbook of Fundamentals – HVAC Applications*. Chapter 36, Owning and Operating Costs. 2007.

Establishing clear and well defined baselines that accurately reflect operating conditions prior to any energy efficiency intervention is central to reporting reliable project savings. The *IPMVP*, incorporated into the operating guidelines of all the U.S. programs summarized in Section 5, provides detailed guidance on how to measure and characterize the baseline condition for energy efficiency projects.

The difficulty with baseline definitions is that they are static, but the buildings and facilities to which they apply are dynamic, changing in response to owners, occupants, economic conditions, regulations, and other pressures. Consequently, all projects need to anticipate the need for baseline adjustments and make provision to accommodate them. A baseline adjustment allows the calculation of the baseline energy consumption under conditions other than those that prevailed before an energy efficiency retrofit occurred.

Baseline adjustments made to account for non-energy factors such as occupancy, scheduling, weather, and industrial production require that the factors be monitored during the baseline and retrofit periods, as is required in individual M&V plans for some of the programs operating in California, Texas and New York.

6. *Free ridership*.

In energy efficiency programs free riders are program participants who would have implemented the program measures without the program's intervention. It is necessary to account for free ridership in order to report net or additional savings.

In many of the programs reviewed in Section 5, administrators, regulators and evaluators account for the inflationary effect of free riders. A component of energy efficiency program design includes analysis of free ridership potential and then writing program rules to minimize its impact. Some examples are: disqualifying applicants who have already contracted to implement the measures in the application, and ensuring that the efficiency ratings of equipment promoted by the program exceed governing codes and standards as well as standard practice.

Impact evaluators have developed survey techniques to measure free ridership in energy efficiency programs. In some cases net-to-gross ratios that incorporate free ridership factors are stipulated based on prior research and/or expert judgment. Detailed examples of both approaches can be found in the California and New York programs.

7. *Measurement uncertainty*.

The experience of the U.S. programs summarized in Section 5 shows that regulators and administrators have become comfortable in including uncertainty estimates as part of any official savings report.

In general, energy efficiency programs account for uncertainty in their savings calculations. The sources of uncertainty can be systematic or random and the most commonly addressed are those due to modeling, instrumentation, or sampling errors. All the U.S. programs described in Section 5 have developed administrative rules and analytical techniques to reduce uncertainty, and to quantify it where possible, although this is most commonly done for only sampling errors. Random sampling errors are always reported by evaluators, as detailed in the *California Evaluation Framework* and adopted by reference by many of the U.S. programs. Sampling error is largely a function of sample size. The *Framework* requires that program savings reports include two components; the point estimate, and the uncertainty associated with the estimate.

Modeling errors, which are difficult to quantify, are largely the result of the miss-application of modeling principles; they are best handled by requiring that trained, experienced staff construct any models used to calculate savings. The *IPMVP* and the *California Evaluation Framework* detail specific procedures for controlling modeling error.

New York, California and Texas all specify the maximum instrument error allowed in their programs, and require periodic calibration. Many programs also reference ASHRAE Guideline 14, which lists expected error values for most M&V instrumentation. Evaluators typically ignore instrument error provided it has been accounted for by program administrators.

8. *Changes in system characteristics*.

   Good program planning and design makes provision for changes in system characteristics. Generally these are addressed under the topic of baseline adjustments, covered in item number 5 above, *Establishing appropriate baseline scenarios*, above. Baseline adjustments are made during a project's performance period, or during an impact evaluation. Issues related to baseline assessments in situations where system characteristics change, are discussed in a number of evaluation guidelines. For example, see *Appendix J: Quality Assurance Guidelines of California's DSM Evaluation Protocols*.[34]

9. *Balancing the convenience of using ex ante measurements against increased accuracy and transaction costs associated with ex post measurement*.

   Energy efficiency program administrators are as concerned with balancing accuracy and transaction costs when reporting energy savings as the Board is for reporting GHG savings. In all of the programs reviewed in this report, administrators and regulators have found ways to use a mix of *ex ante* and *ex post* measurements to simultaneously meet cost-effectiveness and reliability standards in reporting impacts.

[34] California Public Utilities Commission. *Protocols and Procedures for the Verification of Costs, Benefits and Shareholder Earnings from Demand-Side Management Programs: Appendix J.*. California Public Utilities Commission. 1994. www.calmac.org

All program evaluations described in Section 5 use a mix of *ex ante* and *ex post* measurements when reporting impacts. *Ex ante* measurements are used for simple, established technologies for well defined applications with low-risk savings estimates. Rebate programs for compact fluorescent lamp giveaway programs, for example, use *ex ante* estimates to stipulate the per unit savings for each installation. *Ex ante* estimates can incorporate data obtained from *ex post* measurements. In the U.S., California's *DEER Database* has become the nation's de facto warehouse for deemed savings values; the database now has over 130,000 records representing 360 unique measures. New York maintains the *Deemed Savings Database* with *ex ante* savings estimates for the New York market.

In general, energy efficiency program evaluations specify that M&V measurements, including *ex post*, at a level of effort proportionate to the value of the savings. New York, for example, states that the cost of M&V for one of their major programs should not exceed 15 percent of NYSERDA's incentive. Large complex projects, for example combined heat and power on site generation, can involve extensive *ex post* measurement of multiple variables at high frequency rates.

Impact evaluation studies frequently include some level of *ex post* measurement when reviewing direct install programs. The measurement may be as simple as counting pieces of equipment for a sample of projects, or it may be as complex as conducting a billing analysis on a large number of participating facilities. It is not uncommon for evaluators to collect *ex post* data to review programs that report savings based on *ex ante* estimates, an approach that controls administrative transaction costs while allowing for retrospective adjustments.

Conclusions and recommendations based on the material reviewed for this report are discussed next, in Section 7.

Conclusions and Recommendations

The potential for using end-use energy efficiency as a strategy for climate change mitigation is large, but there are methodological challenges for verifying associated GHG emissions reductions and assessing the requirements for additionality. Since energy efficiency currently accounts for only a small fraction of projects in the CDM pipeline, the CDM Board is interested in exploring possibilities for creating an environment that would better enable the provision of qualified energy efficiency projects and programs under CDM. This report examines impact evaluation for end-use energy efficiency programs, with the expectation that current practices can be extended to account for GHG emissions reductions.

Conclusions and recommendations developed from the information prepared for this report are presented next. This Section addresses Task 5 of the Terms of Reference.

7.1 Report Summary

End-use energy efficiency tends to produce relatively small reductions at the individual project level, but can yield impressive levels from large scale programs (programs being made up of a large number of individual projects). Most of the approved CDM methodologies for evaluating GHG reductions from energy efficiency focus on project level measurement, although recently approved small scale project methods do introduce concepts suited to program level activity.

In order to achieve GHG savings from energy efficiency, program level activity is necessary, together with EM&V techniques suited for large-scale programs. Further development of guidelines to facilitate EM&V of energy efficiency programs would enhance opportunities for capturing those reductions. In program-level measurement, a sample of sites is evaluated directly, and the results are modified statistically to develop an accurate representation of the results from the program population. This report shows how impact evaluation approaches used in several energy efficiency programs develop reliable energy savings estimates with acceptable uncertainty limits, at reasonable transaction costs, without requiring project level measurement.

Procedures for evaluating and reporting verified program energy savings are well established, having evolved during the past thirty years into a body of knowledge agreed to and shared by researchers, regulators, equipment vendors, and private and public energy service companies and providers. The literature associated with energy efficiency programs is therefore mature and extensive. A bibliography of current energy efficiency program and program evaluation literature is included in Appendix A.

A selection of existing energy efficiency programs operated in the U.S. and other countries were reviewed in this report using a framework that provides program information and impact evaluation practices. Quantifying GHG emissions reductions resulting from energy efficiency projects and programs may require extending current impact evaluation procedures; however, the existing methods are amenable to supporting such extensions.

As noted earlier in this report, the Secretariat, in a note for the thirty second meeting of the Board, prepared a summary of the key methodological challenges for energy efficiency project activities under CDM. Many of the challenges involve critical questions about verifying GHG emissions reductions and their additionality. These issues were examined in light of lessons learned from the literature review and program descriptions prepared for this report.

7.2 Conclusions

Unfortunately, basic information on efficiency program design and evaluation requirements is neither readily available nor easily comparable between different jurisdictions. However, our review of the current literature and an examination of program offerings and impact evaluation strategies in selected jurisdictions did lead to the following conclusions:

1. **Quantifying savings for end-use energy efficiency programs is an established discipline and its methods can yield reliable and actionable energy savings reports.**

   Entities around the world have been implementing energy efficiency programs since the 1970s. Energy efficiency programs are important for capturing the diffuse benefits of end-use energy efficiency. Their track records and continued operations are testaments to the credibility of impact evaluation practices.

2. **CDM energy efficiency program evaluation approaches can be based on established impact evaluation methods.**

   There is a clear literature on evaluation practices using sampling techniques for measurement as a means of developing program-level estimates. In order to evaluate the effects of energy efficiency programs without incurring prohibitive transaction costs, a sample of the projects or specific installations can be studied and the results scaled to represent the results of the entire program using econometric and statistical techniques. Key documents include recent energy efficiency guidelines produced by the U.S. Environmental Protection Agency,[35] the International Energy Agency,[36] and other sources listed in Appendix A. Although program designs, data availability and quality, regulatory reporting and evaluation requirements vary by jurisdiction there is general agreement on basic approaches for estimating energy savings and associated GHG reductions.

3. **Initiating impact evaluations in areas with varying degrees of data availability and quality is possible given existing data sources, including *stipulated* or *deemed* estimates.**

   Professional evaluators are accustomed to accommodating situations with differences in data availability, data quality and recordkeeping. Evaluators can conduct informative evaluations with varying degrees of rigor based on available data by using techniques that employ existing data modified to accommodate new programs, areas and situations.

   It is reasonable to use *deemed* or *stipulated* estimates for inputs to energy efficiency impact evaluation where relatively accurate data exist or can be developed – including estimates of

[35] S. Schiller, 2007.
[36] H. Vruels, 2005.

energy savings, net-to-gross ratios and/or other inputs. Over time, evaluation results can be used to improve data infrastructure and improved recordkeeping for a variety of programs in different areas and communities. Requirements for rigor and evaluation quality can be revised accordingly over time.

4. **A degree of uncertainty is inherent with measuring the results of energy efficiency but statistical techniques can yield acceptable confidence in the evaluation results**.

   Since the energy efficiency means a certain amount of energy use is avoided and cannot therefore be measured directly, the savings are estimated against a forecast baseline. Energy efficiency programs and evaluation techniques have been evolving for nearly three decades, and even skeptical regulatory agencies have become comfortable with the inherent uncertainty of impact evaluation over time.

   While requirements for rigor vary between jurisdictions, considering the costs of increased rigor versus the improvement in accuracy with more extensive research, many regulatory bodies are satisfied with surveying of projects within a program that achieve a statistical confidence level of 80 percent certainty that the results are within 20 percent of the true impacts. These confidence intervals indicate that there is an equal likelihood that the actual impacts are up to 20 percent higher than the estimated point value, in addition to the possibility that the actual impacts are up to 20 percent lower. Requirements for rigor generally take into consideration the value of reducing uncertainty versus the costs of developing more precise estimates.

5. **The techniques for estimating net savings attributable to specific energy efficiency programs are changing as evaluators face markets saturated with multiple programs.**

   Energy efficiency program impact evaluation, particularly in the U.S., and most particularly, in California's extensive program portfolio, has traditionally placed a great deal of emphasis on differentiating net savings, the savings attributable to a specific program, from gross savings, which can include energy reductions that in some instances would have occurred in the absence of the program. Because an increase in funding for energy efficiency is resulting in increasing numbers of programs, and because of a long history of promoting energy efficiency, California is finding it difficult to attribute savings impacts to a single activity. For resource acquisition programs with direct contact with end-use customers, this may devolve to a simple accounting problem in which records are adjusted so that savings for a project are credited to a single program. In other instances, attribution is more problematic.

   Since net savings are the equivalent of additional savings and/or GHG emissions reductions in climate change terminology, the same issue arises for assessing the additionality of GHG savings attributable to specific energy efficiency programs. Indeed, the same general issue may be on the horizon for assessing additionality of GHG emissions reductions from sources other than energy efficiency. The Board may wish to monitor this issue as the energy efficiency evaluation and regulation communities strive to reach consensus on developing new approaches to this problem.

6. **Basic information on program design, regulation and evaluation requirements is not readily available and not easily comparable between different jurisdictions.**

   Energy efficiency programs have traditionally operated within unique regulatory jurisdictions and there has been little need for cross-jurisdictional comparisons until recently, with the increasing importance of estimating GHG reductions. As a result, information regarding program implementation, regulation, evaluation processes, results and costs are not consistent between jurisdictions, and are typically dispersed in a variety of program and regulatory documents, even within a given program portfolio. This hinders the ability to make cross-comparisons between programs operated in different regions and to understand their similarities and differences.

7.3 Summary of Conclusions

The conclusions discussed above are based on the findings presented in this report. To summarize, the main findings of the report are:

1. Quantifying savings for end-use energy efficiency programs is an established discipline and its methods can yield reliable and actionable energy savings reports.

2. CDM energy efficiency program evaluation approaches can be based on these established impact evaluation methods.

3. Reliable impact evaluations can be conducted, even if project-specific data are not available or cannot be cost-effectively collected for each project, through the use of existing data from comparable efficiency activities or through the use of limited studies to determine values that ca be applied broadly. This approach is called using *stipulated* or *deemed* estimates. However, this approach does require quality-control mechanisms.

4. A degree of uncertainty is inherent with measuring the results of energy efficiency but statistical techniques can yield acceptable confidence in the evaluation results.

5. The techniques for estimating net savings attributable to specific energy efficiency programs are changing in markets saturated with multiple efficiency programs.

6. While not as established as energy savings determination approaches, there are available methodologies for converting efficiency activity savings into avoided GHG emission values.

7.4 Recommendations

Following on the conclusions of this report that end-use energy efficiency evaluation techniques estimate savings impacts with accuracy levels that meet societal and regulatory needs, there are concrete steps that the Board can take to build on this body of knowledge to promote energy efficiency under CDM.

7.4.1 Convene a panel of international end-use energy efficiency experts to develop end-use energy efficiency program implementation templates and program evaluation methodologies.

The Board can convene an international panel of energy efficiency experts to develop a library of templates for end-use energy efficiency programs and evaluation methodologies that would enable certification of real, measurable and verifiable GHG emissions reductions in a manner that conforms to CDM requirements.

Given existing expertise and broad agreement on basic approaches to impact evaluation for end-use energy efficiency programs, it is reasonable to expect that such an effort would be successful. The panel could consider the following basic topics.

7.4.1.1 Program design and implementation templates

Program design and templates could include:

- *Basic program designs* for selected of technologies, approaches and markets. The program designs would include resource acquisition programs, market transformation programs, codes and standards programs, and education and training programs in the commercial, industrial, residential and infrastructure sectors.

- *Recordkeeping and reporting formats* required to verify program accomplishments, energy savings and the resulting GHG emissions reductions.

7.4.1.2 Program methodologies guidelines

Evaluation methodologies could be developed for measuring energy savings and concomitant GHG reductions with adequate accuracy and precision, given the number of independent factors that may affect energy consumption that are not related to energy efficiency improvements (e.g., weather, energy prices, operation and maintenance practices). These can be developed for both currently common efficiency activities (e.g., lighting and motor retrofits) and in the future for more types of activities as the demand for standardized methodologies grows. Topics would address issues raised by the Secretariat including guidance on:

- *Estimating energy savings and GHG emissions reductions* from resource acquisition, market transformation, codes and standards, and education and training programs matched to the program design and implementation templates.

- *Setting boundaries* for the analysis.

- *Sources of recommended information regarding equipment lifetime and other characteristics such as operating hours* for retrofit, replacement and new construction projects, and/or development of databases of *deemed* or *stipulated* values.

- *Strategies for establishing appropriate baseline scenarios* that account for historical usage, changes in operation, technology degradation, naturally occurring conservation and changes in system characteristics.

- *Techniques for estimating free ridership*, and/or development of databases with approved *deemed* or *stipulated* values.

- *Acceptable levels of measurement uncertainty* including sampling guidelines with acceptable measurement and sampling techniques. Varying degrees of rigor could be specified depending on program characteristics, data quality, and the cost versus value of achieving different levels of precision.

- *Balancing the convenience of using ex ante measurements against increased accuracy and transaction costs associated with ex post measurement*. The panel could develop a library of resources for acceptable *deemed* or *stipulated* values, to be used in accord with guidelines for acceptable levels of measurement uncertainty.

- *Methodologies for calculating GHG emissions reductions from energy efficiency programs* and/or acceptable default emissions factors developed for different regions.

- *Requirements for demonstrating additionality*.

7.4.2 Develop deemed savings values

The UNFCCC can sponsor experts to develop a database of deemed or stipulated values for common energy efficiency actions, such as the replacement of 100 watt incandescent light bulbs with a 23 watt compact florescent lamps. These would need to be established with criteria for when they can be used and different values for different applications (e.g., residential versus commercial buildings and indoor versus outdoor). In addition to energy savings, GHG emissions reductions could perhaps also be stipulated for each measure for a range of energy supply scenarios. Quality control and updating of the values would be a suggested part of the process for using stipulated values. An example of such a data base of value sis the California Energy Commission. 2005. Database for Energy Efficient Resources (DEER).
http://www.energy.ca.gov/deer/

7.4.3 Request that current energy efficiency program administrators voluntarily prepare and make public basic information on program implementation and evaluation requirements.

As a first step in developing evaluation guidelines suitable for verifying GHG reductions from end-use energy efficiency programs operating in a variety of venues and regulatory situations, it would be useful to have more complete and comparable information on program implementation, regulatory and evaluation approaches currently in use.

The ability to have basic program and evaluation information available in reasonably consistent reporting formats would facilitate comparisons between programs and serve to highlight issues where CDM program evaluation guidelines must be harmonized to accommodate different conditions and approaches. Having comparable information available for existing programs would facilitate sharing of information about effective program implementation and evaluation strategies.

If UNFCCC/CDM proposed a reporting format that could be completed with out undue effort, current program administrators would have good reason to comply voluntarily with the request. It would enable them to compare their practices with other jurisdictions, prepare for the opportunity to request certified GHG emissions reductions from CDM, and identify and raise issues that arise in the process of compiling the requested information. This type of process is being used successfully in a number of venues where organizations and entities are undertaking to report and certify GHG emissions, even in instances where they are not subject to GHG emissions limits at this time.

The kinds of information requested from current administrators could be based on the framework for analysis used for compiling information presented in this report, including:

- *Program Description*
  Information included in this section includes a program overview, and may contain details regarding program history, maturity, goals, regulatory framework and the sponsoring agency or agencies.

- *Program Size*
  Program budget, and may include information related to timeframe, program cycle, and achievements (MWh, MW, therms, GHGs).

- *Program types*
  A description of the program activity or activities is provided, including to the extent possible, the targeted sectors, customers end-uses.

- *Impact Evaluation Processes*
  Overall approach to evaluation, regulatory requirements, current evaluation protocols or guidelines, budgets, and key issues including, to the extent possible, discussion regarding:
  xii. Reviewers
  xiii. Requirements for rigor, uncertainty
  xiv. Additionality
  xv. Program boundary
  xvi. Timeframe for analysis
  xvii. Data quality and infrastructure
  xviii. Gross savings
  xix. Net savings, free-ridership, technical degradation
  xx. Retention
  xxi. Estimation of GHG reductions
  xxii. Cost-effectiveness

7.5 Summary of Recommendations

The recommendations discussed above are based on the findings presented in this report. To summarize, the two primary recommendations are:

1. Convene a panel of international end-use energy efficiency experts to develop end-use energy efficiency program implementation templates and program evaluation guidelines.

2. Develop deemed savings values for both energy savings and GHG emissions reductions for common energy efficiency actions.

3. Request that current energy efficiency program administrators voluntarily prepare and make public basic information on program implementation and evaluation requirements.

Appendix A - Bibliography

The bibliography is organized into three sections as follows:

1. *Protocols and Guidelines*. These are basic, general references that are frequently cited as part of the specifications for any impact evaluation study. Protocols are general in nature and not program specific. Their use requires developing program-specific program specifications.
2. *Program Specifications & Evaluations*. This section contains program manuals and design documents for energy efficiency programs. If applicable, M&V specifications that must be adhered to by program participants are also referenced. Where available, impact evaluation reports for each of the programs are also listed. Additional impact evaluation resources and reports are also listed here.
3. *Additional papers and Websites.* The references in this section supplement the previous listings, either by exploring issues specific to certifying emissions reductions due to energy efficiency, or providing access to general resources connected to energy efficiency, impact evaluation, M&V, and GHG reductions due to efficiency.

Protocols and Guidelines

The protocols and guidelines listed in this section are general in nature and cover the planning and implementation of an impact evaluation review. Program-specific impact evaluation plans, which reflect particular research goals and unique program characteristics, will build on these protocols. Examples of program-specific impact evaluation investigations are contained in the following section.

1. California Public Utilities Commission (CPUC). 2004. *The California Evaluation Framework*. Prepared by TecMarket Works.
   http://www.cpuc.ca.gov/static/Energy/electric/energy+efficiency/em+and+v/index.htm

   The *California Evaluation Framework* is often cited as a standard in the United States for *program* energy-efficiency evaluation. It provides a great deal of information on evaluation options and principles for impact, process and market evaluations of a wide variety of energy-efficiency program types. Though developed to support the CPUC and California's energy savings targets, it is applicable to all EM&V reviews.

2. Efficiency Valuation Organization. 2007. International Performance Measurement and Verification Protocol (IPMVP), Volumes I and III. San Francisco, USA.
   http://www.evo-world.org.

   The IPMVP provides an overview of current best practice techniques for verifying results of energy efficiency, water and renewable energy *projects* in commercial and industrial facilities. Program evaluation plans often specify using the IPMVP for the M&V of randomly selected review samples. Internationally, it is the most recognized M&V protocol for demand-side energy activities. The IPMVP was developed with sponsorship of DOE and

is currently managed by a non-profit organization that continually maintains and updates the Protocol. It is not a "cookbook" of how to perform specific project evaluations, but provides guidance and key concepts that are used in the United States and internationally.

3. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. 2000. *M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 2.2.* Prepared by Schiller Associates. (updates underway)
   http://ateam.lbl.gov/mv/

   The purpose of this document is to provide guidelines and methods for measuring and verifying the savings associated with federal agency performance contracts. It contains procedures and guidelines for quantifying the savings resulting from energy-efficiency equipment, water conservation, improved operation and maintenance, renewable energy, and cogeneration *projects*. It is an application of the concepts presented in the IPMVP.

4. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). 2002. *Guideline 14-2002 – Measurement of Energy and Demand Savings*. ASHRAE, Atlanta, GA.
   www.ashrae.org

   ASHRAE is the international professional engineering society that has been the most involved in writing guidelines and standards associated with energy efficiency. Compared to the FEMP M&V Guidelines and the IPMVP, Guideline 14 is a more detailed technical document that addresses the analyses, statistics and physical measurement of energy use for determining energy savings at the measure and project level.

5. US Department of Energy and US Environmental Protection Agency. 2007. Model Energy-Efficiency Program Impact Evaluation Guide: a product of the National Action Plan for Energy Efficiency. http://www.epa.gov/cleanenergy/pdf/evaluation_guide.pdf

   The *Model Energy-Efficiency Program Impact Evaluation Guide*, currently in final draft review, provides a framework that jurisdictions and organizations can use to define their "institution-specific" or "program/portfolio-specific" evaluation requirements. To this end, the Guide defines a standard evaluation planning and implementation process, describes several standard approaches that can be used for calculating savings, defines terms, provides advice on key evaluation issues, and lists efficiency evaluation resources. It includes detailed procedures for estimating GHG emissions reductions due to energy efficiency projects.

6. International Energy Agency (IEA). 2006. Evaluating Energy Efficiency Policy Measures & DSM Programs – Volume 1, Evaluation Guidebook, prepared by Harry Vreuls.
   http://dsm.iea.org

7. International Energy Agency (IEA). 2006. Evaluating Energy Efficiency Policy Measures & DSM Programs – Volume 2, Country Reports and Case Examples Used for the Evaluation Guidebook, prepared by Harry Vreuls.
   http://dsm.iea.org

8. Swedish Energy Agency. 2006. Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services: Briefing on existing evaluation practice and experience, prepared by Lars J. Nilsson, Lopes, Fonseca, Labanca.
http://www.evaluate-energy-savings.eu/emeees/downloads/EMEEES_WP2_Report_2007-06-01_eceee.pdf

9. SRC International AIS. 2001. A European Ex-Post Evaluation Guidebook for DSM and EE Service Programs.
http://www.evaluate-energy-savings.eu/emeees/en/home/index.php

References 6 through 9 provide a European perspective on evaluation practices.

10. U.S. Department of Energy (DOE). 2006. *EERE Guide for Managing General Program Evaluation Studies.* U.S. Department of Energy, Washington, D.C.
http://www.eere.energy.gov/,
Or http://www.cpuc.ca.gov/static/Energy/electric/energy+efficiency/em+and+v/index.htm

The EERE guide is a non-technical handbook to assist management design and administer *program* evaluations.

11. World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). 2004. *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*. Washington, DC: World Resource Institute.
http://www.wri.org/climate/

12. World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). 2005. *The Greenhouse Gas Protocol: The GHG Protocol for Project Accounting*. Washington, DC: World Resource Institute.
http://www.wri.org/climate/

13. World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). 2005. *The Greenhouse Gas Protocol: Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects*. Washington, DC: World Resource Institute.
http://www.wri.org/climate/

14. World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). 2005. *The Greenhouse Gas Protocol: Calculation Tools*. Washington, DC: World Resource Institute.
http://www.wri.org/climate/

The World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) convened a multi-stakeholder partnership of businesses, non-government organizations (NGO)s, governments, and others to develop the GHG Initiative. The Initiative's mission is to develop internationally accepted accounting and reporting

protocols for corporate emissions inventories and greenhouse gas mitigation projects and to promote their use by businesses, policy makers, NGO's and other organizations. It consists of the three GHG accounting modules and calculation tools referenced above, as well as outreach activities.

15. Vine, E. and J. Sathaye. 1997. Guidelines for the Monitoring, Evaluation, Reporting, Verification, and Certification of Energy-Efficiency Projects for Climate Change Mitigation: Review of Existing Protocols and Guidelines. Washington, DC: US. Environmental Protection Agency, Climate Policy and Program Division (LBNL-40316). http://ies.lbl.gov/iespubs/40316.pdf

16. Vine, E. and J. Sathaye. 1999. Guidelines for the Monitoring, Evaluation, Reporting, Verification, and Certification of Energy-Efficiency Projects for Climate Change Mitigation. Washington, DC: US. Environmental Protection Agency, Climate Policy and Program Division (LBNL-41543). http://ies.lbl.gov/iespubs/41543.pdf

17. Vine, E. and J. Sathaye. 2000. Best Practices Guide: Monitoring, Evaluation, Reporting, Verification, and Certification of Climate Change Mitigation Projects. Berkeley, CA: Lawrence Berkeley National Laboratory. http://www.iie.org/programs/energy/pdfs/Monitor%20Verif%20Climate%20Change.pdf

    The three Vine and Sathaye reports investigate the use of EM&V guidelines and protocols for quantifying GHG emissions reductions due to energy efficiency projects and programs. The authors propose a methodology, discuss key issues regarding baseline and gross impact calculations, and provide specific guidance on reporting, certifying and quality assurance for certifying savings.

18. Violette, D., C. Mudd, and M. Keneipp, 2001. *An Initial View on Methodologies for Emission Baselines: Energy Efficiency Case Study*. OECD Environment Directorate and International Energy Agency.

    The Violette paper investigates the use of system load shapes to estimate GHG emissions baselines, and by extension savings. The findings suggest that the use of dispatch models vs. emissions factors for estimating GHG emissions reductions may result in increased accuracy, but the lack of time-of-use data may limit jurisdictions to emissions factors only.

19. California Public Utilities Commission (CPUC). 2001. *Standard Practice Manual (SPM) Economic Analysis of Demand-Side Management Programs*. http://www.energy.ca.gov/greenbuilding/documents/background/07-J_CPUC_STANDARD_PRACTICE_MANUAL.PDF

    The SPM provides the background and technical explanations for conducting commonly used cost-effectiveness tests of DSM programs.

20. California Public Utilities Commission. (CPUC) 2001. *A Framework for Planning and Assessing Publicly-Funded Energy Efficiency*. Prepared by Regional Economic Research, et al.
http://www.cpuc.ca.gov/static/Energy/electric/energy+efficiency/em+and+v/index.htm or www.calmac.org

21. California Public Utilities Commission (CPUC). 1994. *Quality Assurance Guidelines for Statistical and Engineering Models*. 1994. Pacific Consulting Services.
www.calmac.org/publications/2005.pdf

The CPUC documents 19 - 21cover specific technical aspects faced in evaluation studies.

22. Electric Power Research Institute (EPRI). 1992. *DSM Evaluation -- Six Steps for Assessing Programs.*
www.epri.com

23. Electric Power Research Institute (EPRI). 1991. Impact Evaluation of Demand-Side Management Programs; Volume 1: A Guide to Current Practice.
www.epri.com

24. Electric Power Research Institute (EPRI). 2001. Market Transformation: A Practical Guide to Designing and Evaluating Energy Efficient Programs.
www.epri.com

The EPRI reports represent early efforts to synthesize EM&V practices as they evolved in the latter part of the 20th century.

Program Specifications and Evaluations

The documents and Websites listed in this section represent the application of the principles discussed in the references cited in the **Error! Reference source not found.** section. They are program-specific, designed to achieve defined program and evaluation goals.

25. CALifornia Measurement Advisory Council (CALMAC)
http://www.calmac.org/

26. Consortium for Energy Efficiency's Market Assessment and Program Evaluation (MAPE) Clearinghouse.
http://www.cee1.org/eval/clearinghouse.php3

The Websites listed in references 25and 26 are warehouses for past evaluation and market studies. The CALMAC site is specific to California and contains over 700 reports dating to 1990. The MAPE site is a repository for non-California studies; it currently lists over 400 evaluation and market assessments studies dated back to 1996.

27. California Energy Commission. 2005. Database for Energy Efficient Resources (DEER).

http://www.energy.ca.gov/deer/

28. Efficiency Vermont. 2006. Technical Reference User Manual (TRM): Measure Savings Algorithms and Cost Assumptions through Portfolio 42. Available upon request.
http://www.efficiencyvermont.com/pages/

29. New York State Energy Research and Development Authority (NYSERDA). *Deemed Savings Database*. Available upon request.
www.nyserda.org

The databases and manuals in references 27 - 29 provide energy and demand reductions, useful lifetimes, incremental costs, and lifetime savings for a wide range of energy efficiency measures. Their primary functions are to support the use of stipulated savings in programs, and to support the EM&V of technology-specific energy efficiency installations. The energy savings estimates are based on engineering analysis, laboratory tests, and observed performance. Each of the references contains documentation to support assumptions and sources used in promulgating the published values. The DEER database contains over 130,000 records; the Deemed Savings Database lists over 400 measures.

30. California Public Utilities Commission (CPUC). 1998. Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Side Management Programs.
http://www.calmac.org/cadmac-protocols.asp#

31. Pacific Gas and Electric (PG&E). 2007. 2007 Nonresidential Retrofit – Demand Response (NRR-DR) Procedures Manual.
http://www.pge.com/biz/rebates/2007_incentive_application/nrr-dr.html

32. California Public Utilities Commission (CPUC). 2006. California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals. Prepared by The TecMarket Works Team.
http://www.cpuc.ca.gov/static/Energy/electric/energy+efficiency/em+and+v/index.htm

33. Quantum Consulting. 2005. 2003 Statewide Nonresidential Standard Performance Contract (SPC) Program Measurement and Evaluation Study. Prepared for Southern California Edison.
http://www.calmac.org/

References 30 - 33 are specific examples of M&V and EM&V as practiced in California under the guidance of the CPUC. The PG&E *Procedures Manual* lays out the reporting and M&V specifications for the utility's non-residential programs. The CPUC *Evaluation Protocols* prescribe how evaluations are to be conducted. The Quantum *Measurement and Evaluation Study* is an example of an impact evaluation review conducted under the auspices of the CPUC.

34. California Best Practices Project Advisory Committee. 2004. *National Energy Efficiency Best Practices Study*.
http://www.eebestpractices.com/

The Best Practices Study is a survey of exemplary energy efficiency programs operating in the United States. The Study resulted in a database of energy efficiency best practices to be used as a resource in designing, implementing, and managing energy efficiency programs.

35. New York State Energy Research and Development Authority (NYSERDA). 2006. Enhanced Commercial and Industrial Performance Program: Program Opportunity Notice No. 1101.
http://www.nyserda.org/funding/

36. New York State Energy Research and Development Authority (NYSERDA). 2006. *Commercial/Industrial Performance Program (CIPP) Final Report - Measurement and Verification.* Prepared by Nexant, Inc. Available upon request from NYSERDA.
http://www.nyserda.org/Energy_Information/evaluation.asp

37. New York State Energy Research and Development Authority (NYSERDA). 2006. Commercial Industrial Performance Program (CIPP) - Market Characterization, Market Assessment and Causality (MCAC) Evaluation Final Update Report. Prepared by Nexant, Inc. Available upon request from NYSERDA.
http://www.nyserda.org/Energy_Information/evaluation.asp

References 35 - 37 describe a commercial/industrial energy efficiency program operated in New York State. *Program Opportunity Notice No. 1101* specifies the program requirements and includes a detailed section on the use of M&V in reporting project savings. The remaining two documents are evaluation reports; the first focusing on gross savings impacts, the second on net-to-gross ratios and net impacts.

38. Energy Trust of Oregon. 2005. Evaluation of the 2002 and 2003 Transition Commercial Retrofit Programs. Prepared by Quantec LLC.
http://www.energytrust.org/

39. Energy Trust of Oregon. 2005. *Production Efficiency Program: Process and Impact Evaluability Assessment*. Prepared by Research Into Action, Inc.
http://www.energytrust.org/

The Energy Trust of Oregon is charged with administering rate-payer funded energy efficiency programs in Oregon. References 38 and 39report on the evaluations of two of those programs.

40. MidAmerican Energy Company. 2007. Efficiency Bid Program: Customer Program Manual.
http://www.midamericanenergy.com/html/energy6k.asp

MidAmerican's Efficiency Bid Program operates in Iowa and targets commercial and industrial customers. The *Program Manual* describes a range of M&V requirements that are scaled to match the value of a projects expected savings, with more complex and larger projects required to conduct more detailed M&V and results reported with greater precision.

41. Oncor Electric Delivery. 2007. 2008 Commercial and Industrial Standard Offer Program: Program Manual for Project Sponsors. http://www.txuelectricdelivery.com/electricity/teem/services/candi/program.aspx

42. Texas Public Utilities Commission. 2005. *Measurement and Validation Guidelines*. http://www.puc.state.tx.us/electric/projects/30331/052505/m%26v%5Fguide%5F052505.pdf

43. Summit Blue Consulting. 2005. *Independent Audit of Texas Energy Efficiency Programs in 2003 and 2004*. Prepared for the Public Utility Commission of Texas. www.summitblue.com

References 40 - 43 cover the implementation and evaluation of energy efficiency programs operating in Texas. Oncor's *Program Manual for Project* Sponsors includes measure and project level M&V specifications for existing and new construction building projects, drawing in part on the Commission's approved *Measurement and Validation Guidelines*. The Summit Blue *Independent Audit* reports on a high level evaluation of the Texas programs.

44. State of Wisconsin, Department of Administration, Division of Energy. 2006. *Focus on Energy Statewide Evaluation: Business Programs Impact Evaluation Report – Fiscal Year 2006*. Evaluation Contractor: PA Government Services Inc. http://www.focusonenergy.com/data/common/dmsFiles/E_BP_RPTI_FY06ImpactEvaluation.pdf

45. Ontario Power Authority. 2007. *OPA EM&V Framework, Draft Version 1.0*. http://www.powerauthority.on.ca/Page.asp?PageID=122&ContentID=6271&SiteNodeID=137&BL_ExpandID=XXXX NEW

46. Harmelink, Mirjam; Harmesen, Nilsson. 2007. From theory based policy evaluation to Smart Policy Design: Lessons learned from 20 ex-post evaluations of energy efficiency instruments. ECEEE 2007 Summer Study Proceedings. http://www.eceee.org/

47. Jullian, Patrick; Hita, Rosenstein. 2007. Review of good practices in measuring and verifying energy savings among French energy efficiency actors – a strong will to put quality securing methods forward. ECEEE 2007 Summer Study Proceedings. http://www.eceee.org/

48. Amato, Andrew. 2007. *Sustainable energy in UK housing – Monitoring and targeting using integrated datasets*. ECEEE 2007 Summer Study Proceedings. http://www.eceee.org/

References 46 - 48 are all from the proceedings for the European Council for an Energy Efficient Economy 2007 Summer Study Conference and provide insight into the practice of impact evaluation in the EU. By one attendee's estimate, about one half of the Conference presentations covered US programs, indicating that the European evaluation community is looking to the US for guidance. Indeed, Harmelink's paper, reference 43, states that monitoring information "…is often insufficient to determine the impact [of energy efficiency policy instruments] on energy savings…"

Additional Papers

The papers in this section explore the challenges in quantifying GHG emissions reductions due to energy efficiency projects; most also suggest mechanisms for meeting those challenges.

49. Figueres, Christiana and Philips, Michael. Scaling Up Demand–Side Energy Efficiency Improvements through Programmatic CDM, prepared for Energy Sector Management Assistance Program and The World Bank Carbon Finance Unit. 2007. www.esmap.org

50. Schiller, Steven R. 2007. Energy Efficiency as a Climate Change Mitigation Strategy. ACEEE Summer Study, 2006. www.aceee.org

51. Schiller, Steven R. 2007. Survey of Energy Efficiency Evaluation Measurement and Verification Guidelines and Protocols: An Initial Review of Practices and Gaps and Needs. Prepared for the California Public Utilities Commission and the California Evaluation Outreach Initiative, May 2007.

52. Niederberger, Anne Arquit. 2007. *Energy Efficiency Projects in CDM and JI: Seminar issue paper.* Prepared for the UNIDO/CTI/UK Trade & Investment Seminar March 2007, Vienna.

53. Niederberger, Anne Arquit, and Spalding-Fecher. 2006. *Demand-Side energy efficiency promotion under the Clean Development Mechanism: lessons learned and future prospects.* Energy for Sustainable Development Vol X No. 4 December 2006 51-64.

54. Dickerson, Chris Ann, and McCormick, Mike. Securing the Link Between Energy Efficiency Savings and Greenhouse Gas Reductions: How Will Energy Efficiency Evaluation Protocols Measure Up? Conference Proceedings: International Energy Program Evaluation Conference, Brooklyn, NY, August 17-19, 2005. www.iepec.org

55. Mahone, Douglas; Hall, Megdal, Keating, Ridge. 2005. Codes and Standards White Paper on Methods for Estimating Savings. Prepared for Marian Brown, PhD, Southern California Edison in support of Statewide Codes and Standards Program Evaluation.

Additional Websites

Building Owners and Managers Association (BOMA) International.
http://www.boma.org/TrainingAndEducation/BEEP/

California's Appliance Efficiency Program (including California Title 20 Appliance

Standards). www.energy.ca.gov/appliances/index.html

California Climate Action Registry. www.climateregistry.org

California Demand Response Programs. www.energy.ca.gov/demandresponse/index.html

California Energy Commission Efficiency Programs. http://www.energy.ca.gov/efficiency/

California Green Building Initiative. www.energy.ca.gov/greenbuilding/index.html

California Investor-Owned Utility Energy-Efficiency Programs. www.californiaenergyefficiency.com/

California Municipal Utilities Association (CMUA). www.cmua.org

California Solar Initiative. www.cpuc.ca.gov/static/energy/solar/index.htm

Climate Trust, The. www.climatetrust.org

Efficiency Vermont. www.efficiencyvermont.com/pages/

Efficiency Valuation Organization (EVO). www.evo-world.org

European Council for an Energy Efficient Economy. http://www.eceee.org/

European Union Energy Efficiency Directive, measurement, monitoring and evaluation website: http://www.evaluate-energy-savings.eu/emeees/en/home/index.php

International Energy Program Evaluation Conference (IEPEC). http://www.iepec.org/

Maine State Energy Program. www.state.me.us/msep/

Northeast Energy Efficiency Council (NEEC). http://www.neec.org

Northeast Energy Efficiency Partnerships (NEEP). www.neep.org

Northwest Energy Efficiency Alliance (NEEA). http://www.nwalliance.org/

New York State Energy Research and Development Authority (NYSERDA). www.nyserda.org

Texas Energy Efficiency Programs - http://www.texasefficiency.com/

Western Renewable Energy Generation Information System (WREGIS). www.westgov.org/wieb/wregis/

United Nations Framework Convention for Climate Change, Clean Development Mechanism (CDM). http://cdm.unfccc.int/index.html

U.S. Department of Energy

Efficiency and renewable energy: www.eere.energy.gov
1605b Program: http://www.eia.doe.gov/environment.html
U.S. Environmental Protection Agency:

Clean Energy Programs: http://www.epa.gov/solar/epaclean.htm
Energy Star http://www.energystar.gov/
World Business Council for Sustainable Development (WBCSD). www.wbcsd.org

World Resources Institute (WRI). www.wri.org

Appendix B - Glossary

The following definitions are from the (U.S.) *National Action Plan for Energy Efficiency (2007). Model Energy Efficiency Program Impact Evaluation Guide*. Prepared by Steven R. Schiller, Schiller Consulting, Inc. www.epa.gov/eeactionplan

Additionality: A criterion that says avoided emissions should only be recognized for project activities or programs that would not have "happened anyway." While there is general agreement that additionality is important, its meaning and application remain open to interpretation.

Adjustments: For M&V analyses, factors that modify baseline energy or demand values to account for independent variable values (conditions) in the reporting period.

Allowances: Allowances represent the amount of a pollutant that a source is permitted to emit during a specified time in the future under a cap and trade program.. Allowances are often confused with *credits* earned in the context of project-based or offset programs, in which sources trade with other facilities to attain compliance with a conventional regulatory requirement. Cap and trade program basics are discussed at the following EPA Web site: http://www.epa.gov/airmarkets/cap-trade/index.html.

Analysis of covariance (ANCOVA) model. A type of regression model also referred to as a "fixed effects" model.

Assessment boundary: The boundary within which all the primary effects and significant secondary effects associated with a project are evaluated.

Baseline: Conditions, including energy consumption and related emissions, that would have occurred without implementation of the subject project or program. Baseline conditions are sometimes referred to as "business-as-usual" conditions. Baselines are defined as either project-specific baselines or performance standard baselines.

Baseline period: The period of time selected as representative of facility operations before the energy-efficiency activity takes place.

Bias: The extent to which a measurement or a sampling or analytic method systematically underestimates or overestimates a value.

California Measurement Advisory Council (CALMAC): An informal committee made up of representatives of the California utilities, state agencies, and other interested parties. CALMAC provides a forum for the development, implementation, presentation, discussion, and review of regional and statewide market assessment and evaluation studies for California energy-efficiency programs conducted by member organizations.

Co-benefits: The impacts of an energy-efficiency program other than energy and demand savings.

Coincident demand: The metered demand of a device, circuit, or building that occurs at the same time as the peak demand of a utility's system load or at the same time as some other peak of interest, such as building or facility peak demand. This should be expressed so as to indicate the peak of interest, e.g., "demand coincident with the utility system peak." Diversity factor is defined as the ratio of the sum of the demands of a group of users to their coincident maximum demand. Therefore, diversity factors are always equal to one or greater.

Comparison group: A group of consumers who did not participate in the evaluated program during the program year and who share as many characteristics as possible with the participant group.

Conditional Savings Analysis (CSA): A type of analysis in which change in consumption modeled using regression analysis against presence or absence of energy-efficiency measures.

Confidence: An indication of how close a value is to the true value of the quantity in question. Confidence is the likelihood that the evaluation has captured the true impacts of the program within a certain range of values, i.e. precision.

Cost-effectiveness: An indicator of the relative performance or economic attractiveness of any energy-efficiency investment or practice. In the energy-efficiency field, the present value of the estimated benefits produced by an energy-efficiency program is compared to the estimated total costs to determine if the proposed investment or measure is desirable from a variety of perspectives, e.g., whether the estimated benefits exceed the estimated costs from a societal perspective.

Database for Energy-Efficient Resources (DEER): A California database designed to provide well-documented estimates of energy and peak demand savings values, measure costs, and effective useful life.

Deemed savings: An estimate of an energy savings or energy-demand savings outcome (gross savings) for a single unit of an installed energy-efficiency measure that (a) has been developed from data sources and analytical methods that are widely considered acceptable for the measure and purpose and (b) is applicable to the situation being evaluated.

Demand: The time rate of energy flow. Demand usually refers to electric power measured in kW (equals kWh/h) but can also refer to natural gas, usually as Btu/hr, kBtu/hr, therms/day, etc.

Direct emissions: Direct emissions are changes in emissions at the site (controlled by the project sponsor or owner) where the project takes place. Direct emissions are the source of avoided emissions for thermal energy-efficiency measures, e.g. avoided emissions from burning natural gas in a water heater.

Effective useful life: An estimate of the median number of years that the efficiency measures installed under a program are still in place and operable.

Energy efficiency: The use of less energy to provide the same or an improved level of service to the energy consumer in an economically efficient way; or using less energy to perform the same function. "Energy conservation" is a term that has also been used, but it has the connotation of doing without in order to save energy rather than using less energy to perform the same function.

Energy-efficiency measure: Installation of equipment, subsystems or systems, or modification of equipment, subsystems, systems, or operations on the customer side of the meter, for the purpose of reducing energy and/or demand (and, hence, energy and/or demand costs) while maintaining a comparable level of service. Measures are generally regarded as activities that affect just one end use (e.g., the lighting system, the HVAC system, or an industrial process)

Engineering model: Engineering equations used to calculate energy usage and/or savings. These models are usually based on a quantitative description of physical processes that transform delivered energy into useful work such as heat, lighting, or motor drive. In practice, these models may be reduced to simple equations in spreadsheets that calculate energy usage or savings as a function of measurable attributes of customers, facilities, or equipment (e.g., lighting use = watts × hours of use).

Error: Deviation of measurements from the true value.

Evaluation: The performance of studies and activities aimed at determining the effects of a program; any of a wide range of assessment activities associated with understanding or documenting program performance, assessing program or program-related markets and market operations; any of a wide range of evaluative efforts including assessing program-induced changes in energy-efficiency markets, levels of demand or energy savings, and program cost-effectiveness.

***Ex ante* savings estimate:** Forecasted savings used for program and portfolio planning purposes. (From the Latin for "beforehand.")

***Ex post* evaluation estimated savings:** Savings estimates reported by an evaluator after the energy impact evaluation has been completed. (From the Latin for "from something done afterward.")

Free driver: A non-participant who has adopted a particular efficiency measure or practice as a result of the evaluated program.

Free rider: A program participant who would have implemented the program measure or practice in the absence of the program. Free riders can be total, partial, or deferred.

Gross savings: The change in energy consumption and/or demand that results directly from program-related actions taken by participants in an efficiency program, regardless of why they participated.

Impact evaluation: An evaluation of the program-specific, directly induced changes (e.g., energy and/or demand usage) attributable to an energy-efficiency program.

Independent variables: The factors that affect energy use and demand, but cannot be controlled (e.g., weather or occupancy).

Indirect emissions: Changes in emissions that occur at the emissions source (e.g., the power plant). Indirect emissions are the source of avoided emissions for electric energy-efficiency measures.

Interactive factors: Applicable to IPMVP Options A and B; changes in energy use or demand occurring beyond the measurement boundary of the M&V analysis.

Leakage: In the context of avoided emissions, emissions changes resulting from a project or program not captured by the primary effect (typically the small, unintended emissions consequences). Sometimes used interchangeably with "secondary effects," although leakage is a more "global" issue whereas secondary, interactive effects tend to be considered within the facility where a project takes place.

Load shapes: Representations (graphs, tables, databases) that describe energy consumption rates as a function of another variable such as time or outdoor air temperature.

Market effect evaluation: An evaluation of the change in the structure or functioning of a market, or the behavior of participants in a market, that results from one or more program efforts. Typically the resultant market or behavior change leads to an increase in the adoption of energy-efficient products, services, or practices.

Market transformation: A reduction in market barriers resulting from a market intervention, as evidenced by a set of market effects, that lasts after the intervention has been withdrawn, reduced, or changed.

Measurement: A procedure for assigning a number to an observed object or event.

Measurement and verification (M&V): Data collection, monitoring, and analysis associated with the calculation of gross energy and demand savings from *individual sites or projects*. M&V can be a subset of program impact evaluation.

Measurement boundary: The boundary of the analysis for determining direct energy and/or demand savings.

Metering: The collection of energy consumption data over time through the use of meters. These meters may collect information with respect to an end-use, a circuit, a piece of equipment, or a whole building (or facility). Short-term metering generally refers to data collection for no more than a few weeks. End-use metering refers specifically to separate data collection for one or more end-uses in a facility, such as lighting, air conditioning or refrigeration. Spot metering is an instantaneous measurement (rather than over time) to determine an energy consumption rate.

Monitoring: Gathering of relevant measurement data, including but not limited to energy consumption data, over time to evaluate equipment or system performance, e.g., chiller electric demand, inlet evaporator temperature and flow, outlet evaporator temperature, condenser inlet temperature, and ambient dry-bulb temperature and relative humidity or wet-bulb temperature, for use in developing a chiller performance map (e.g., kW/ton vs. cooling load and vs. condenser inlet temperature).

Net savings: The total change in load that is attributable to an energy-efficiency program. This change in load may include, implicitly or explicitly, the effects of free drivers, free riders, energy-efficiency standards, changes in the level of energy service, and other causes of changes in energy consumption or demand.

Net-to-gross ratio (NTGR): A factor representing net program savings divided by gross program savings that is applied to gross program impacts to convert them into net program load impacts.

Non-participant: Any consumer who was eligible but did not participate in the subject efficiency program, in a given program year. Each evaluation plan should provide a definition of a non-participant as it applies to a specific evaluation.

Normalized annual consumption (NAC) analysis: A regression-based method that analyzes monthly energy consumption data.

Participant: A consumer that received a service offered through the subject efficiency program, in a given program year. The term "service" is used in this definition to suggest that the service can be a wide variety of services, including financial rebates, technical assistance, product installations, training, energy-efficiency information or other services, items, or conditions. Each evaluation plan should define "participant" as it applies to the specific evaluation.

Peak demand: The maximum level of metered demand during a specified period, such as a billing month or a peak demand period.

Persistence study: A study to assess changes in program impacts over time (including retention and degradation).

Portfolio: Either (a) a collection of similar programs addressing the same market (e.g., a portfolio of residential programs), technology (e.g., motor efficiency programs), or mechanisms (loan programs) or (b) the set of all programs conducted by one organization, such as a utility (and which could include programs that cover multiple markets, technologies, etc.).

Potential studies: Studies conducted to assess market baselines and savings potentials for different technologies and customer markets. Potential is typically defined in terms of technical potential, market potential, and economic potential.

Precision: The indication of the closeness of agreement among repeated measurements of the same physical quantity.

Primary effects: Effects that the project or program are intended to achieve. For efficiency programs, this is primarily a reduction in energy use per unit of output.

Process evaluation: A systematic assessment of an energy-efficiency program for the purposes of documenting program operations at the time of the examination, and identifying and recommending improvements to increase the program's efficiency or effectiveness for acquiring energy resources while maintaining high levels of participant satisfaction.

Program: A group of projects, with similar characteristics and installed in similar applications. Examples could include a utility program to install energy-efficient lighting in commercial buildings, a developer's program to build a subdivision of homes that have photovoltaic systems, or a state residential energy-efficiency code program.

Project: An activity or course of action resulting in an energy-efficiency improvement at a single facility or site involving one or more energy-efficiency measures. An energy-efficiency measure and a project can be the same, but only if the project has just one measure (e.g. a lighting retrofit).

Rebound effect: A change in energy-using behavior that yields an increased level of service and occurs as a result of taking an energy-efficiency action.

Regression analysis: Analysis of the relationship between a dependent variable (response variable) to specified independent variables (explanatory variables). The mathematical model of their relationship is the regression equation.

Reliability: Refers to the likelihood that the observations can be replicated.

Reporting period: The time following implementation of an energy-efficiency activity during which savings are to be determined.

Resource acquisition program: Programs designed to directly achieve energy and or demand savings, and possibly avoided emissions

Retrofit isolation: The savings measurement approach defined in IPMVP Options A and B, and ASHRAE Guideline 14, that determines energy or demand savings through the use of meters to isolate the energy flows for the system(s) under consideration.

Rigor: The level of expected confidence and precision. The higher the level of rigor, the more confident one is that the results of the evaluation are both accurate and precise.

Secondary effects: Unintended impacts of the project or program such as rebound effect (e.g., increasing energy use as it becomes more efficient and less costly to use), activity shifting (e.g., when generation resources move to another location), and market leakage (e.g., emission changes due to changes in supply or demand of commercial markets). These secondary effects can be positive or negative.

Spillover: Reductions in energy consumption and/or demand caused by the presence of the energy-efficiency program, beyond the program-related gross savings of the participants. There can be participant and/or non-participant spillover.

Statistically adjusted engineering (SAE) models: A category of statistical analysis models that incorporate the engineering estimate of savings as a dependent variable.

Stipulated values: See “deemed savings.”

Takeback effect: See “rebound effect.”

Uncertainty: The range or interval of doubt surrounding a measured or calculated value within which the true value is expected to fall within some degree of confidence.